

Lemieux Declaration

**IN THE UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF DELAWARE**

GENERAL ELECTRIC COMPANY,

Plaintiff,

v.

LPP COMBUSTION, LLC,

Defendant.

C.A. No. 1:22-cv-00720-GBW

EXPERT DECLARATION OF DR. PATRICK LEMIEUX, PH.D.

TABLE OF CONTENTS

I.	Scope of engagement	4
II.	Education and Experience.....	4
III.	Understanding of the Law	7
	A. Person of Ordinary Skill in the Art	7
	B. Date of the Invention.....	7
	C. Claim Construction	8
	D. Indefiniteness	10
IV.	Background on the Asserted Patents.....	10
	A. '396 Patent	10
	B. '080 and '924 Patent	15
V.	Opinions	17
	A. Term 1: “diluent gas” ('396 Patent, Cls. 1 & 10)	17
	B. Term 2: “inert” ('396 Patent, Cls. 1 & 10).....	21
	C. Term 8: “acceptable range” ('080 Patent, Cls. 1, 19, 20 & '924 Patent, Cls. 1 & 16)	26
VI.	Right to Supplement.....	28

LIST OF APPENDICES/EXHIBITS

No.	Description
APPENDIX A	<i>Curriculum Vitae</i> of Dr. Patrick Lemieux
APPENDIX B	List of Materials Considered
EXHIBIT 1	Drysdale, “An Introduction to Fire Dynamics” (2nd ed., 1999)
EXHIBIT 2	McGraw-Hill Dictionary of Scientific and Technical Terms (6th ed., 2003)
EXHIBIT 3	Chambers Dictionary of Science and Technology (1999)
EXHIBIT 4	Webster’s II New College Dictionary (1999)
EXHIBIT 5	A Dictionary for the Petroleum Industry (1st ed., 1991)
EXHIBIT 6	Dictionary of Petroleum Exploration, Drilling & Production (2006)

I. SCOPE OF ENGAGEMENT

1. The Defendant General Electric Company has engaged me to provide my opinions regarding the meaning that certain disputed claim terms of U.S. Patent Nos. 7, 770,396 (“the ’396 Patent”), 7,435,080 (“the ’080 Patent”), and 7,934,924 (“the ’924 Patent”) would have to persons of ordinary skill in the art.

2. I expect to potentially be asked to provide testimony on my opinions. In explaining my opinions, I expect to rely on the documents and testimony used in this declaration, as well as any additional materials that I have relied upon to reach my opinions. To the extent I obtain additional information, I reserve the right to supplement my opinions accordingly, and to use that additional information during testimony at deposition and/or trial.

3. I am being compensated at a rate of \$550 per hour for consulting and \$750 per hour for deposition and trial testimony. My opinions are objective, and compensation for my services is not contingent on my opinions or the outcome of this action.

4. In preparation of this declaration, I have received and relied upon a number of documents. I also performed independent research in this matter. Attached as **Appendix B** is a list of materials considered for the purposes of this declaration. The opinions expressed in this declaration are based on facts currently known to me. I reserve the right to rely upon additional information that becomes available to me after the date of this report and, if necessary, to supplement or modify my opinions accordingly.

II. EDUCATION AND EXPERIENCE

5. I am a Professor of Mechanical Engineering at the California Polytechnic State University, San Luis Obispo. I have held this position since 2012. Prior to becoming a full professor, I was an Associate Professor of Mechanical Engineering, also at California

Polytechnic State University, starting in 2007. More recently, from March 2022 through March 2023, I worked as a visiting professor at the Munich University of Applied Sciences, where I was awarded a Teaching Fellowship for one semester. Over there, I taught classes in gas turbine propulsion and thermodynamics.

6. In formulating my opinions, I have relied upon my training, knowledge, and experience in the relevant art. A copy of my current *Curriculum Vitae* is provided (**Appendix A**), and it provides a comprehensive description of my background, experience, and academic and employment history, including a list of my publications in the relevant art. As my *Curriculum Vitae* shows, I have experience with gas turbine engines for power production, including in the areas involving thermo-fluid analyses and combustion.

7. I have a Bachelor of Science in Engineering, Mechanical Engineering from the University of New Brunswick (1991). I also have a Master of Science in Thermal Power from the Cranfield Institute of Technology, England (1992). I received my Ph.D. in Mechanical Engineering from the California Institute of Technology (1999).

8. I am a Licensed Mechanical Engineer (M 32617, California Board for Professional Engineers and Land Surveyors) since 2003.

9. I am also the Co-Founder and Principal Engineer of polyXengineering, Inc. ('polyX'), located in San Luis Obispo, CA. polyXengineering, Inc. is a consulting firm committed to solving technical engineering problems in many areas, including mechanical engineering issues relating to gas turbine engines, among others.

10. Outside of my teaching career, I have been employed at Honeywell International as a Staff Engineer. At Honeywell, I performed analyses on gas turbine engines and fuel cells,

and developed gas turbine engine modeling programs. I have also been employed by IBM Canada Ltd., where I implemented new manufacturing processes for microchip substrates.

11. I have published more than 30 articles in fields ranging from turbine and engine design, wind turbines, rocket motors, to heat transfer in nucleate boiling regimes. A list of the articles I have published or contributed to are listed in my *Curriculum Vitae* (**Appendix A**). I continue to receive funding from governmental organizations and private industry, and to present at domestic and international conferences. Additionally, I have provided my expert opinion in legal matters. I have also lectured, advised, researched, and consulted in for the relevant art for more than 30 years regarding the technology described and claimed in the three patents at issue in this case.

12. I have received multiple awards over my career, including: Bently Professor of Mechanical Engineering, California Polytechnic State University, San Luis Obispo, 2010-2014, 2017-present; Chrones Professor of Mechanical Engineering, California Polytechnic State University, San Luis Obispo, 2007-2008; the Exponent ‘Excellence Award’ for engineering work on the modeling of the World TradeCenter, 2002; the Charles Lee Powell Graduate Fellowship, Caltech, 1997-1998; the Natural Sciences and Engineering Research Council of Canada PGS-A and PGS-B scholarships for tenure at Caltech, 1992-1996; the Daniel and Florence Guggenheim Fellowship in Jet Propulsion, 1992-1994; the Athlone-Vanier Engineering Fellowship, for graduate studies in the U.K. (three awarded per year in Canada), 1991-1992; and, the John Stephens Memorial Prize for highest standing in the graduating Mechanical Engineering Class of 1991 at the University of New Brunswick, Canada.

13. I am an Associate Fellow of the American Institute of Aeronautics and Astronautics and a member of American Society of Mechanical Engineers, Society of

Automotive Engineers, American Society of Heating, Refrigerating and Air Conditioning Engineers, American Society of Engineering Educators, and Aircraft Owners and Pilots Association. In addition, I am a private pilot rated for multi-engine aircraft.

III. UNDERSTANDING OF THE LAW

14. I am not an attorney and offer no opinions on the law. I have relied on instructions from counsel as to the applicable legal standards to use in arriving at my opinions in this report. Below is my understanding regarding the relevant legal standards based on those instructions.

A. Person of Ordinary Skill in the Art

15. I understand that a person having ordinary skill in the art (“POSITA”) is a hypothetical person considered to have the normal skills and knowledge in the relevant technical field at the time of the invention and without the benefit of hindsight.

16. Having reviewed the patents at issue in this case, I consider a POSITA to be an individual with at least a Bachelor’s degree in Mechanical or Chemical Engineering, and having approximately three years’ experience (or who has an advanced degree in these areas with some work experience) in the field of combustion devices, including with the design, testing, or development of combustion devices.

B. Date of the Invention

17. I understand that when the date of invention is based on the filing of a patent application, the date of invention is the earliest effective filing date of a patent’s claims. I understand that the earliest effective filing date of a patent’s claims may, in some circumstances, be proven to predate the actual filing date of the U.S. application for that patent. For example, if an application is a continuation of an earlier application (a “parent application”), the earliest

effective filing date of the claims resulting from the later application may be the filing date of the parent application, but only if the parent application's disclosure satisfies the enablement and written description requirements for those claims. Similarly, if a non-provisional application claims priority to an earlier provisional application, the earliest effective filing date of the claims resulting from the non-provisional application may be the filing date of the provisional application, but only if the provisional application's disclosure satisfies the enablement and written description requirements for those claims.

C. Claim Construction

18. I understand that claim construction is a matter of law decided by the court and that claim terms are interpreted as one of ordinary skill in the art would understand them at the time of the invention, in view of the patent and evidence related thereto.

19. In construing the claims, I understand that one must first look to what is called the "intrinsic evidence" of the patent. The intrinsic evidence includes the language of the claims, the patent specification, the prosecution history, and documents cited on the face of the patent and/or during its prosecution history.

20. I understand that claim terms are generally given their ordinary and customary meaning, which is the meaning that the term would have to a person of ordinary skill in the art in question at the time of the claimed invention. I further understand that there are two exceptions to this general rule: (1) when a patentee acts as his or her own lexicographer—meaning the patentee has clearly set forth a definition of the disputed claim term other than its plain and ordinary meaning—or (2) when the patentee makes a clear and unmistakable disclaimer of the full scope of a claim term either in the specification or during prosecution.

21. I understand that claims are generally construed to cover the embodiments disclosed in the patent specification, particularly when those embodiments are characterized as “preferred.” I also understand that claims do not have to cover all embodiments disclosed in the patent, and that certain claims may be limited to specific embodiments.

22. Nevertheless, I understand that limitations from the embodiments in the specification must not be read into the claims. I understand that it is improper to read limitations from a preferred embodiment described in the specification—even if it is the only embodiment—into the claims absent a clear indication in the intrinsic record that the patentee intended the claims to be so limited.

23. I understand that a presumption exists that the same terms appearing in different portions of the claims should be given the same meaning, unless it is clear from the specification and prosecution history that the terms have different meanings at different portions of the claims. By contrast, I understand that different words or phrases used in separate claims are presumed to indicate that the claims have different meanings and scope. To the extent that the absence of such difference in meaning and scope would make a claim superfluous, I understand a presumption exists that the difference between claims is significant. I understand that the presence of a dependent claim that adds a particular limitation gives rise to a presumption that the limitation in question is not present in the independent claim.

24. I understand that after looking at intrinsic evidence, “extrinsic evidence” may be considered. Extrinsic evidence can include expert testimony, dictionaries, learned treatises, and other literature that provide an understanding of the background technology and prior art—provided that the extrinsic evidence does not contradict claim meaning that is unambiguous in light of the intrinsic evidence of the patent.

D. Indefiniteness

25. I understand that claims of an issued U.S. Patent are presumed to be valid. Specifically, I understand that, according to 35 U.S.C. § 282, “[e]ach claim of a patent (whether in independent, dependent, or multiple dependent form) shall be presumed valid independently of the validity of other claims; dependent or multiple dependent claims shall be presumed valid even though dependent upon an invalid claim.

26. I understand that generally the party challenging the validity of an issued U.S. patent bears the burden of proof to demonstrate that such patent is invalid.

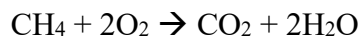
27. I understand that the challenging party’s burden of proof at trial is by clear and convincing evidence, which is a higher standard than the preponderance of the evidence standard that applies to proving patent infringement. I understand that for evidence to be clear and convincing, it must produce in the mind of the finder of fact an abiding conviction that the truth of the factual contentions is highly probable.

28. I understand that under the version of 35 U.S.C. § 112 applicable to these patents, a patent must “conclude with one or more claims particularly pointing out and distinctly claiming the subject matter which the applicant regards as his invention.” I understand a claim is invalid under this section for being indefinite if the claim read in light of the specification delineating the patent, and the prosecution history, fail to inform, with reasonable certainty, those skilled in the art about the scope of the invention. I understand that claims may use terms of degree without being indefinite, but can be infinite where they do not provide objective boundaries for those of skill in the art when read in light of the specification and the prosecution history.

IV. BACKGROUND ON THE ASSERTED PATENTS

A. ’396 Patent

29. The '396 Patent is directed to vaporizing liquid fuels—including, in particular, liquified higher hydrocarbons—to be burned as fuel in a combustor such as a premixed combustor or a diffusion combustor. '396 Patent, Abstract. Generally speaking, combustion processes can be described as either diffusion flame combustion systems or lean, premixed combustion systems. Diffusion flame combustion systems were developed first, and function by delivering both the fuel and oxidizer to the combustion zone in an unmixed state. Mixing of the fuel and air (oxidizer) and combustion take place simultaneously. Because the mixing occurs via diffusion, there are local regions where the fuel and oxidizer are present in near-stoichiometric levels, which can generate very high temperature flames. “Near-stoichiometric” refers to the ideal ratio of oxidizer to fuel reactants in a combustion reaction, one where the products contain no leftover oxidizer or fuel. For instance, the stoichiometric combustion of methane with oxygen is shown below:



30. So-called “premix” combustion systems, as their name implies, thoroughly premix the fuel with air before the mixture enters the combustor. “Lean” refers to the ratio of fuel-to-air, with the fuel fraction kept below the ideal stoichiometric level. Lean premix combustors were designed to produce lower NO_x emissions than diffusion flame combustors by eliminating hot spots in the combustion zone. *See also id.*, 1:30-41 (“This lean mixture of natural gas and air burns at a lower temperature than conventional diffusion flame combustors, thereby producing lower levels of pollutants, including oxides of nitrogen (NO_x) in the exhaust stream.”). A lean premixed turbine may also operate in diffusion flame mode during operating conditions such as startup and shutdown.

31. The patent describes vaporizing the liquid/liquified fuel using an oxygen-reduced air stream; the claims refer to this oxygen-reduced air stream as “diluent gas.” I note that the specification never uses the terms “diluent” or “diluent gas,” but instead refers “oxygen-reduced stream” or “reduced oxygen stream” interchangeably. *Id.*, 3:49-52. The specification describes an issue in which “[i]n order to generate a lean, **premixed**, prevaporized flame using liquid fuels or liquefied gases ... the liquids must first be evaporated into a carrier gas (normally air) to create a fuel gas (i.e. a fuel vapor/air mixture) which then may be mixed with additional combustion air prior to arrival at the flame front,” however “a phenomenon known as auto-ignition can occur with such vaporized liquid fuel/liquefied gas and air mixtures.” *Id.*, 1:56-67. The specification refers to “auto-ignition” as “the spontaneous ignition of the fuel prior to the desired flame location in the combustion device,” which can lower efficiency and damage the device. *Id.*, 1:67-2:7. In particular, damage to the device could occur when there is combustion at the point of mixing, instead of the combustion zone, as intended. Autoignition or undesired combustion is not possible at a point upstream of the combustion zone if no oxidizer is present (*e.g.*, air).

32. I note that the patent’s use of “auto-ignition” is somewhat unusual in these circumstances. The patent refers to “auto-ignition” as “the spontaneous ignition of the fuel prior to the desired flame location in the combustion device. This premature ignition can occur, for example, as a result of normal, premature, or other heating of the fuel that can occur as the fuel is fed to the combustion device.” *Id.*, 1:67-2:5. A somewhat-related concept is “flammability.” Flammability is a range of fuel-to-air vapor concentration ratios at which combustion is possible when ignited by an external source or sufficient energy. For instance, there is a lower flammability limit (LFL) at which the concentration of fuel in air is too low for the fuel vapor to

support combustion, and there is an upper flammability limit (UFL) at which the fuel concentration is too high and the air concentration too low to support combustion.

33. The claims of the '396 Patent purport to solve this issue of “auto-ignition” through the introduction of an inert diluent gas. *Id.*, Cl. 1. The patent describes the use of a vaporization unit 1 which includes a liquid/liquidized fuel source 3 and a reduced oxygen gas stream source 2. *Id.*, 5:47-50. As described in Claim 1, a fuel gas is then produced “using a liquid fuel comprising hydro-carbon molecules and a diluent gas.” *Id.*, Cl. 1.

34. In certain “preferred embodiments,” the '396 Patent is designed to be “used with existing lean, premixed combustion devices configured to combust natural gas.” *Id.*, 2:58-61. Furthermore, the '396 Patent describes configuring the gas vaporization unit used to “supply a reduced oxygen vaporized fuel gas to the turbine engine 14 such that no modification to the fuel gas distribution system of the engine 14 is necessary.” *Id.*, 7:47-51; *see also* Fig. 3. The patent describes that “[t]his is accomplished by mixing the fuel gas with an inert, reduced oxygen stream to keep the energy content of the fuel gas equal to that of natural gas on either a mass or volumetric basis depending upon the metering method used by the combustion device” (*id.*, 9:34-37) as shown in Figure 8, below:

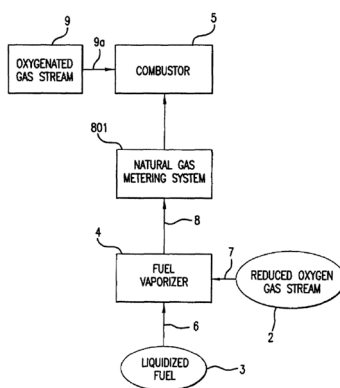
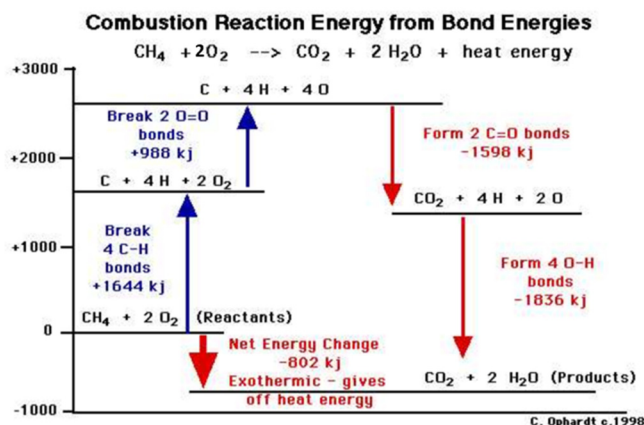


FIG.8

35. The energy released during a combustion reaction comes from the breaking and formation of chemical bonds and the relative energy invested/released by that process. For instance, as shown below, during the combustion of methane, energy is required to break the four C-H (+1644 kJ/mol) bonds and two O=O (+988 kJ/mol) bonds of the methane molecule and two oxygen molecules, respectively. But a greater amount of energy is released by the formation of two C=O (-1598 kJ/mol) bonds and four O-H (-1836 kJ/mol) bonds. The excess energy is given off as heat:¹



36. As the patent states, “the heating value of a fuel gas is approximately proportional to the number of carbon atoms in the gas molecule. Therefore, pentane (C_5H_{12}) has approximately 5 times the heating value of the primary component of natural gas, methane (CH_4)” (on a volume basis). *Id.*, 7:61-65. Essentially, this is because of the greater number of bonds that are broken (C-C bonds, C-H bonds, and O=O bonds) and created (C=O bonds and O-H bonds) per hydrocarbon molecule. The amount of energy released during the combustion reaction of a hydrocarbon can be represented as heat of combustion (ΔH), shown in the table below:

¹ See C. E. Ophardt, “Energy of Combustion,” Elmhurst College Virtual Chembook (2003), available at <http://chemistry.elmhurst.edu/vchembook/512energycombust.html>

Table 1.13 Heats of combustion^a of selected fuels at 25°C (298 K)

		$-\Delta H_c$ (kJ/mol)	$-\Delta H_c$ (kJ/g)	$-\Delta H_{c,air}$ (kJ/g(air))	$-\Delta H_{c,ox}$ (kJ/g(O ₂))
Carbon monoxide	CO	283	10.10	4.10	17.69
Methane	CH ₄	800	50.00	2.91	12.54
Ethane	C ₂ H ₆	1423	47.45	2.96	11.21
Ethene	C ₂ H ₄	1411	50.35	3.42	14.74
Ethyne	C ₂ H ₂	1253	48.20	3.65	15.73
Propane	C ₃ H ₈	2044	46.45	2.97	12.80
<i>n</i> -Butane	<i>n</i> -C ₄ H ₁₀	2650	45.69	2.97	12.80
<i>n</i> -Pentane	<i>n</i> -C ₅ H ₁₂	3259	45.27	2.97	12.80
<i>n</i> -Octane	<i>n</i> -C ₈ H ₁₈	5104	44.77	2.97	12.80
<i>c</i> -Hexane	<i>c</i> -C ₆ H ₁₂	3680	43.81	2.97	12.80
Benzene	C ₆ H ₆	3120	40.00	3.03	13.06
Methanol	CH ₃ OH	635	19.83	3.07	13.22
Ethanol	C ₂ H ₅ OH	1232	26.78	2.99	12.88
Acetone	(CH ₃) ₂ CO	1786	30.79	3.25	14.00

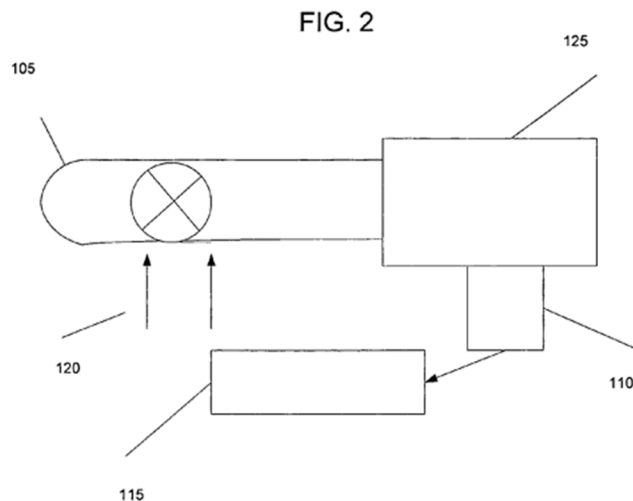
See Drysdale, “An Introduction to Fire Dynamics” (2nd ed., 1999) (**Exhibit 1**) at pg. 19 (Table 1.13).

B. '080 and '924 Patent

37. I understand that the '080 and '924 Patents are related to one another and share a common specification. The Abstract of the patents describe the invention as “system[s] and method[s] for providing continuous measurement and control of a combustion device by altering the fuel composition delivered thereto.” '080 Patent, Abstract. The Abstract further states that “[t]he system includes devices for sensing related information, such as fuel characteristics, combustion characteristics, or other device characteristics, and controlling the performance of the combustion device based on the sensed information.” *Id.* Based on these sensed characteristics, additives may be added to the fuel to maintain “consistent combustion device performance ... despite varying fuel characteristics.” *Id.* According to the patents, premixed, low-emissions combustion devices are highly sensitive to variations in fuel composition, and therefore accurate control of additive is particularly important. *Id.* at 7:33-37. For instance, “stability problems can arise due to the variable composition of natural gas or other feed gases.” *Id.* at 7:51-64.

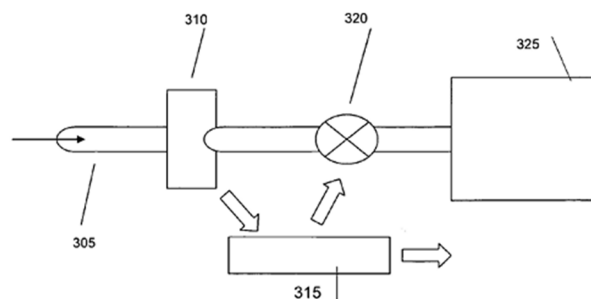
38. According to the patents, there are two main types of embodiments for control: a direct method that measures combustor performance characteristics, and an indirect method that measures fuel characteristics prior to combustion as a proxy for how the fuel will affect combustor performance. *Id.*, 1:61-2:9, 2:27-46. If “monitored results” are outside the “acceptable range” for the sensed characteristic, “an appropriate amount of ... additive is added to the fuel feed.” *Id.*

39. For example, Figures 2 and 3 “illustrate[] an example of a method that determines combustion performance directly” by sensing at least one “combustion characteristic.” *Id.*, 8:33-37. The combustion characteristic is analyzed and the “controller determines if the fuel composition should be changed to correct a combustion dynamics problem.” *Id.*, 8:47-49. If there is a problem, for example, “fuel composition is outside of predetermined acceptable range for combustion device operation,” then “the proper change to the fuel composition (e.g., addition of appropriate additive to fuel feed) is determined” and “a signal is sent to the additive system indicating that a certain amount of additive should be mixed into the fuel stream.” *Id.*, 8:52-63.



40. With regard to Figures 4 and 5, combustion performance is determined indirectly via a sensed “fuel characteristic” such as fuel composition, and “if the composition of the fuel is changing, such that the regulating quantity indicates a flame stability problem, the composition can be altered” by sending “a signal [] to the additive system 320 controlling the amount of either diluent or reactive species to be mixed into the fuel stream to obtain the required composition.” *Id.*, 9:16-50. Accordingly, in both disclosed embodiments, which additive is “appropriate”—either a “diluent” (also referred to as a “retardant”) or “reactive species” (also referred to as an “enhancer”) for example—is determined by comparing the sensed characteristic to an “acceptable range” for that characteristic.

FIG. 4



V. OPINIONS

A. Term 1: “diluent gas” (’396 Patent, Cls. 1 & 10)

41. Having considered the proposed constructions from both parties, I agree with GE that a POSITA would not understand the meaning of the claimed “diluent gas” to encompass fuel gases.

42. Starting with the claim language, the claims require “producing a fuel gas using a liquid fuel comprising hydrocarbon molecules and a diluent gas.” Accordingly, the claimed “fuel gas” includes of separate components: a vaporized liquid fuel comprising hydrocarbon

molecules, and a diluent gas. Based on this claim language, a person of ordinary skill would consider the juxtaposition of “diluent gas,” as compared to “a liquid fuel comprising hydrocarbons,” in arriving at the conclusion that the claimed diluent is not a fuel.

43. Also, as stated in the claim language, the purpose of the “diluent gas” is to “suppress” reactions upstream of the combustion zone. Indeed, that is consistent with a POSITA’s understanding of the word “diluent”—a diluent as used in this field is something that dilutes or reduces the effect of another substance. Here, a fuel gas is diluted “such that reaction of the fuel gas upstream of the combustion zone is suppressed.” ’396 Patent, Cl. 1; *see also id.* at 3:10-13 (“By mixing the fuel with a gas stream that has an appropriately reduced concentration of oxygen, reaction of the vaporized fuel can be prevented or sufficiently delayed so as to avoid auto-ignition.”). As I discuss below, whether a fuel reacts or combusts is related to the concentration of the fuel and the concentration of an oxidizer such as air present in the mixture. It is this tendency to react with air (*i.e.*, combust) that has the potential to lead to autoignition upstream of the combustion zone.

44. In this field, a “fuel” is a substance that reacts rapidly with a source of oxygen (an oxidizer) to produce heat in an exothermic chemical reaction. In most instances, mixing fuels (such as two different hydrocarbons) will have a diminishingly small effect on the mixture’s ability to react in the presence of oxygen, assuming the total concentration of fuel is not changed. For instance, in the example of a “dual-fuel” combustion system that mixes two fuels to achieve combustion, a person of ordinary skill in the art would not refer to one fuel as “diluting” the other, despite the fact that they may have different characteristics (for instance, mixing a high-octane index, high-volatility fuel such as gasoline with a high-cetane index, high-ignitability fuel, such as diesel). Both are fuels.

45. Conversely, the patent discusses diluting vaporized liquid fuels with non-fuels in order to prevent reactions that would lead to unwanted autoignition. As I discussed in the Background section above, the '396 Patent states the goal of utilizing higher hydrocarbon liquid/liquified fuels in an otherwise standard combustion device while avoiding “modification to the fuel gas distribution system of the engine 14.” *Id.*, 7:47-51; *see also* Fig. 3. The specification describes the method by which this is accomplished is by mixing the vaporized liquid fuel with a diluent gas “to keep the energy content of the fuel gas equal to that of natural gas on either a mass or volumetric basis.” *Id.*, 9:34-37. The specification gives the example of using pentane (C_5H_{12}), which has “approximately 5 times the heating value of the primary component of natural gas, methane (CH_4)” (by volume)—in which case one would have to mix “one part vaporized pentane gas” with “four parts reduced oxygen gas” to achieve an equivalent heating value of methane, the main component of natural gas. *Id.*, 7:65-8:3. This is an oversimplified example from the patent, and the analysis would be much more complex. However, a POSITA reading this passage would understand that you obviously cannot dilute pentane with methane (or any other hydrocarbon fuel) to achieve the heating value of methane (the primary component of natural gas. Using the numbers from Drysdale, Table 1.13, presented above, the combustion of methane released 800 kJ/mol whereas the combustion of pentane releases 3259 kJ/mol. The combustion of one part pentane with four parts methane would release an average of 1,291 kJ/mol, significantly higher (over 50%) than methane alone. Given that methane has the lowest volumetric heat of combustion of all alkanes, there is no combination of two or more hydrocarbons possible to produce the same heat release as methane.

46. As I discussed above with regard to flammability limits, there is an upper flammability limit (UFL) on the concentration of any fuel per unit volume of mixture above

which it will not be ignited by an external source, because not enough oxygen is present in the mixture. The UFL for methane is about 15% and the UFL for ethane is about 12%. Drysdale, (**Exhibit 1**) at 77 (Table 3.1). A vaporized fuel in the absence of air (*i.e.*, as the source of oxygen), meaning the concentration of O₂ is zero or nearly zero, would not combust. Adding other vaporized/gaseous fuels will not change this as long as the mixture stays below above UFL. Therefore, if the vaporized “liquid fuel comprising hydrocarbon molecules” recited in, for instance, Claim 1 of the ’396 Patent were above UFL, adding additional fuels would not change the fact that it would not combust.

47. Conversely, once the vaporized liquid fuel comprising hydrocarbons mixes with oxygen, if “auto-ignition” upstream of the combustion zone (*e.g.*, the premixing zone) would occur (**scenario 1**), then adding a second fuel comprising hydrocarbons would generally have very little to no practical effect on changing whether auto-ignition will occur (**scenario 2**). Because the UFLs of many fuels are comparatively similar (in particular, ethane and methane have similar UFLs), in most circumstances where there would be “auto-ignition” upstream of the combustion zone of, for example, ethane in scenario 1, the properties of the combined fuel mixture in scenario 2, adding methane, would generally also be susceptible to auto-ignition assuming all else is kept equal. *Compare* ’396 Patent, Cl. 1. Conversely, adding a diluent such as nitrogen or carbon dioxide would have a **large effect** on these properties because now the fuel has been diluted and there are inert gas particles to act as ballast and absorb some of the energy of the reaction. *See* Drysdale (**Exhibit 1**) at 103 (“A flammable mixture may be rendered non-flammable by the addition of a suitable suppressant. Additives such as nitrogen and carbon dioxide act as inert diluents, increasing the thermal capacity of the mixture (per unit mass of

fuel) and thereby reducing the flame temperature, ultimately to below the limiting value when flame propagation will not be possible (Section 3.1.4).”)

48. In comparison, I understand that LPP’s construction would allow for a fuel gas to be considered a “diluent gas” as long as the oxygen concentration was reduced relative to ambient air. LPP seems to be arguing that a fuel with a reduced oxygen concentration relative to air would be considered a “diluent,” *even if the oxygen concentration were zero*, meaning the fuel was 100% pure. However, a POSITA would not consider the inherent characteristic of the fuel itself to be changed because it lacks oxygen and is, in essence, pure fuel. As stated previously, a POSITA would not consider it to be a dilution to mix one fuel with another fuel. Indeed, in the special case of ethane/methane mixtures, both components are already naturally present in ‘natural gas’ in varying concentrations. Thus, forcing a change in their relative concentration does not in the eyes of a POSITA, in and of itself, ‘dilute’ the product or reform it in a way that its characteristics are significantly changed, as opposed to blending it with non-combustible components, *e.g.*, N₂ or exhaust products.

49. Additionally, LPP’s construction could lead to peculiar results. By focusing solely on the oxygen content of the “diluent gas,” LPP’s construction would potentially include gases that can react directly with the hydrocarbon containing vaporized liquid fuel, such as certain peroxide and epoxy-containing gases or alcohol or oxidizers like nitrous oxide that have an oxygen concentration less than ambient air. In such cases, there would be “reactions” far upstream of the combustion zone, in the vaporizer itself, which is clearly contrary to the intended invention.

50. For the above reasons, I agree with GE’s construction of “diluent gas.”

B. Term 2: “inert” (’396 Patent, Cls. 1 & 10)

51. I have considered both parties' constructions of "inert." Both parties agree that "inert" in the context of the disputed claims involves at least a "reduced oxygen concentration relative to air." I agree with GE that a POSITA at the time of invention—in the context of the claims and the specification—would construe the claims' use of "inert" to also exclude diluent gases containing hydrocarbons.

52. Starting with the claims, "inert" modifies "diluent gas." Accordingly, an inert diluent gas is a subset of diluent gases as a whole. As noted above, I agree with GE that a diluent gas in the context of the claims is a non-fuel gas that is added to the fuel flow. Next, the specification, as read by a POSITA, clearly supports distinguishing between diluents that contain hydrocarbons and those that do not. At column 6 of the patent, there is a discussion of "reduced oxygen gas stream source[s]" that may be used to practice certain embodiments of the invention. '396 Patent, 6:8-31. The relevant passage begins by stating that "more work (*i.e.*, energy) is required to produce a gas stream with a lower oxygen content ... [t]hus, in some embodiments, the oxygen content from the stream source 2 is just low enough to suppress auto-ignition." *Id.*, 6:20-25. The specification goes on to say "[i]n other embodiments of the invention, the reduced oxygen gas stream source 2 contains no oxygen" and that "[i]n some of these embodiments"—*i.e.*, those that contain no oxygen—"the gas supplied by reduced oxygen gas stream source 2 is ***inert***," and "in yet ***other*** embodiments, the gas from source 2 contains hydrocarbons." *Id.*, 6:25-31 (emphasis added). The full text of this passage is reproduced below:

Thus, in some embodiments, the oxygen content from the stream source 2 is just low enough to suppress auto-ignition by the required amount, which may be above or below the LOI. In other embodiments of the invention, the reduced oxygen gas stream source 2 contains no oxygen. In some of these embodiments, the gas supplied by reduced oxygen gas stream source 2 is inert; in yet other embodiments, the gas from source 2 contains hydrocarbons (e.g., methane and/or higher hydrocarbons).

53. Accordingly, it would be clear to a POSITA that the patentee is drawing a distinction between diluent streams that are inert and those that contain hydrocarbons. Because the patentee chose to use the term “inert” in its claims, a POSITA would understand that the claimed diluent does not contain hydrocarbons, in my opinion. The specification does not elaborate on the final embodiment in which “the gas from source 2 contains hydrocarbons (e.g., methane and/or higher hydrocarbons).” *Id.*, 6:29-31. However, elsewhere the specification describes using vitiated exhaust gas from a pre-burner to provide a reduced oxygen stream. *Id.*, 3:21-24. In some instances, there could be hydrocarbons left over from an incomplete combustion process. However, the patent makes clear that in such instances the reduced oxygen gas would not be considered “inert.”

54. “Inert” had at the time of invention (and still has) a well-understood meaning in this field as appreciated by a POSITA at the time of alleged invention. The following dictionaries give similar definitions that represent a consensus among POSITAs concerning the meaning “inert,” in my opinion. *See* McGraw-Hill Dictionary of Scientific and Technical Terms (6th ed., 2003) (**Exhibit 2**) (“inert” [*Sci Tech*]: Lacking an activity, reactivity, or effect.), (“inert gas” see noble gas), (“noble gas” [*Chem*] A gas in group 0 of the periodic table of elements; it is monatomic and, with limited exceptions, chemically inert. Also known as inert gas; rare gas.); Chambers Dictionary of Science and Technology (1999) (**Exhibit 3**) (“inert” (Chem): Not readily changed by chemical means.), (“inert gases” (Chem): See “noble gases”), (“noble gases” (Chem): Elements helium, neon, argon, krypton, xenon and radon-222, much used (except the last) in gas-discharge tubes. (Radon-222 has short-lived radioactivity, half-life less than four days). Their outer (valence) electron shells are complete, thus rendering them inert to all the usual chemical reactions; a property for which argon, the most abundant, finds increasing

industrial use. The heavier ones, Rn, Xe, Kr, are known to form a few unstable compounds, *e.g.*, XeF₄. Also inert gases, rare gases.); Webster's II New College Dictionary (1999) (**Exhibit 4**) ("Inert", Chem: 3a. displaying no chemical activity. 3b. Displaying chemical activity only under special or extreme conditions.); A Dictionary for the Petroleum Industry (1st ed., 1991) (**Exhibit 5**) ("inert gas", n: In chemistry, gases that have a filled outer electron shell and thus do not easily react with other substances. Examples are helium, argon, neon, and xenon.); Dictionary of Petroleum Exploration, Drilling & Production (2006) (**Exhibit 6**) ("inert gas": a gas that will not chemically react with other substances. Helium, neon, argon, krypton, xenon, and radon are inert gases.). All of these dictionaries refer to "inert" as essentially meaning that the material naturally resists chemical reactivity. Some dictionaries additionally discuss "inert gases" meaning the noble gases, which are elementary gases that are known for their lack of chemical reactivity.

55. I understand that LPP has argued that "'inert' is context-specific." LPP's Opening Claim Construction Brief at 9. However, this does not support their position. Firstly, there are some elements/molecules which are uniformly considered "inert" by definition, although reactions may be hypothetically feasible under some rare circumstances. As shown in my citations to several dictionaries above, the noble gases of helium, neon, argon, krypton, xenon, and radon are such elements. Furthermore, "An Introduction to Fire Dynamics" (Second Edition) by Dougal Drysdale, a leading textbook in the art published around at the time of the claimed invention, consistently refers to some molecules—N₂ and CO₂ specifically—that are the prototypical examples of inert gases for use in this field. *See* Drysdale (**Exhibit 1**) at 103 ("A flammable mixture may be rendered non-flammable by the addition of a suitable suppressant. Additives such as nitrogen and carbon dioxide act as inert diluents, increasing the thermal

capacity of the mixture (per unit mass of fuel) and thereby reducing the flame temperature, ultimately to below the limiting value when flame propagation will not be possible (Section 3.1.4).”), 230 (“Thus, ‘inert’ diluents (*e.g.*, N₂ and CO₂) cool the reaction zone by increasing the effective thermal capacity of the atmosphere (per mole of oxygen) (Sections 1.2.5 and 3.5.4) and chemical suppressants such as the halons inhibit the flame reactions (Sections 1.2.4 and 3.5.4).”). This means that an inert substance is **non-flammable**, and thus clearly excludes hydrocarbons. The specification itself discusses embodiments utilizing “an appropriate level of non-combustible nitrogen combined with a reduced level of oxygen” to prevent auto-ignition. ’396 Patent, 3:59-64; *see also id.* at Figs. 3 and 5(a) (utilizing N₂ and N₂/CO₂ as diluents). Likewise, the specification of the ’924 Patent and the ’080 Patent identify some of the same gases when explaining the term “inert diluent.” *See, e.g.*, ’080 Patent, 6:29-36. Conversely, there are some compounds that a POSITA would not understand to be inert in this context, such as a hydrocarbon.

56. Second, the “context” of the claims in this instance is a combustion device such as a gas turbine, in which hydrocarbons are the primary fuel and not considered to be “inert” by a POSITA. LPP’s construction would potentially achieve the absurd result wherein a *pure hydrocarbon* containing gas with *no or practically no concentration of oxygen* could be considered inert, as long as the end result prevents “or slow[s]” a chemical reaction that could lead to autoignition. This is contrary to the understanding of a POSITA in this field.

57. Furthermore, evidence cited by LPP during the European prosecution history further confirms that in this context hydrocarbons would not be considered inert by a POSITA. In response to a reference (Gleason) that disclosed using a “nearly inert” vitiated exhaust stream to vaporize liquid fuels, LPP argued that, despite the specification describing the

use of “vitiating exhaust gas from a pre-burner” (’396 Patent, 3:21-25) as an embodiment, not all such vitiated exhaust streams would qualify as “inert” because they may contain “reactive species, such as NO, OH, CH₂O and many others, that will adversely shorten auto-ignition time.” 10/22/2013 Response in EP1549881 at 2 (**App. P**). As discussed above, if the exhaust stream additionally contained hydrocarbons (*e.g.*, as the product of a “rich” combustion), the exhaust stream would likewise not be considered inert.

58. Accordingly, I agree with GE’s construction of “inert” in the context of the asserted claims as meaning “reduced oxygen concentration relative to air, and not containing hydrocarbons.”

C. Term 8: “acceptable range” (’080 Patent, Cls. 1, 19, 20 & ’924 Patent, Cls. 1 & 16)

59. In my opinion, neither the claims themselves nor the specifications of the ’080 and ’924 Patents provide sufficient guidance to inform a POSITA what ranges are “acceptable” as that term is used in the challenged claims. The claims of both patents require comparing a sensed characteristic (either a “combustion characteristic” in regard to the ’924 Patent claims or a “fuel characteristic” in regard to the ’080 Patent claims) to “an acceptable range.” ’080 Patent, Cls. 1, 19, & 20; ’924 Patent, Cls. 1 & 16. What is “acceptable” depends on a number of factors, including the particular application that the combustion device is being used for, the various hardware components of the combustion device and their maximum or minimum tolerances, and importantly, the opinions of the engineers operating the system.

60. Examining the examples LPP gives in its brief, I do not find that an “acceptable range” is provided for any of them. LPP begins by giving the example of flame color as an example of a combustion characteristic, and fuel performance as an example fuel characteristic.

LPP's Opening Claim Construction Brief at 16. But the specification gives no indication what spectrum or range of wavelengths of flame colors would be deemed "acceptable," instead simply referring to a number of spectroscopic and chemiluminescence sensors without further elaboration. *See* '080 Patent at 4:34-47, 59-64.

61. With regard to "fuel performance," LPP seemingly refers to indices of fuel performance such as a Wobbe Index or a Weaver Index. *Id.* at Cls. 8 & 9. As with flame color, the patent likewise gives no indication as to an "acceptable range" of an index of fuel performance, instead stating that "[t]he controller can also maintain constant combustion properties by such methods as maintaining a constant index of combustion." '080 Patent at 4:19-21. "Constant" is not a range. In practice, maintaining a constant Wobbe index is not feasible when dealing with varying fuel compositions. But, the patent gives no indication or teaching as to what amount of variation from "constant" would be deemed "acceptable."

62. Finally, LPP gives the example of flame speed, citing the statements from the patent that certain combustion systems "operate in a narrow stability region between flashback and blow-off" and that "[f]lame speed must generally equal flow velocity for stable combustion." LPP's Opening Claim Construction Brief at 16-17. While this is true in a very general sense, besides identifying the boundary conditions ("Flashback occurs when the flame speed is faster than the flow velocity through the combustor, allowing flame propagation upstream. Blow-off occurs when the flame speed is slower than the flow velocity through the combustor, allowing the flame to be blown downstream and extinguished." ('080 Patent at 7:40-44)), the patent gives no indication what range within those boundaries is "acceptable." Because a POSITA would generally consider flashback and blow-off to be unwanted, the "acceptable" range would have endpoints before flashback occurs on one extrema, and before blow-off on the other extrema.

The specification gives no indication where these endpoints lie and, accordingly, how large a range is “acceptable.”

63. These examples are not the only ones that lack guidance as to what the patentee considers to be an “acceptable” range. The specification as a whole is bereft of any such examples. Instead the individual practitioners are left to decide for themselves what is “acceptable.” Accordingly, I believe a POSITA would be unable to determine whether the set of parameters (i.e., range) selected for a combustion device would or would not be considered “acceptable” within the meaning of the claims.

VI. RIGHT TO SUPPLEMENT

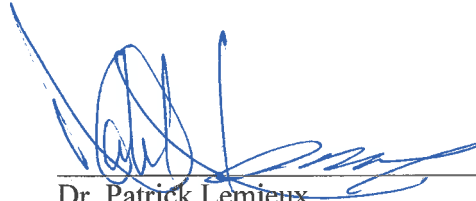
64. In the event additional information come to light that is relevant to my opinions in this declaration or further issues arise that concern the subject matter in my declaration, I expressly reserve the right to supplement, modify, or amend my opinions as stated in this declaration as well as the bases supporting my opinions. I also reserve the right to consider and comment on additional evidence, that may be presented by LPP or its experts.

65. I further reserve the right to supplement and/or amend this declaration to submit a reply declaration based on any information or contentions expressed by LPP or its experts attempting to rebut my opinions in this declaration.

66. If called upon to testify at any trial or hearing in this matter, I may provide demonstrative aids. I reserve the right to use demonstratives or other exhibits at trial in support of my opinions in any of my expert reports and/or supplements thereto.

Pursuant to 28 U.S.C. § 1746 and the Federal Rules, I declare under the penalty of perjury under the law of the United States of America that the statements made herein are true and accurate.

Executed on May 10th, 2023 date, in San Luis Obispo, CA.
(date) (location)


Dr. Patrick Lemieux

Lemieux Appendix A

PATRICK LEMIEUX, Ph.D., P.E.

Professor of Mechanical Engineering
California Polytechnic State University, San Luis Obispo
San Luis Obispo, CA 93407
Tel.: (805) 756-5583
E-mail: plemieux@calpoly.edu

PROFESSIONAL EXPERIENCE

- polyXengineering Inc., (www.polyxengineering.com) San Luis Obispo***, San Luis Obispo, California. 2016-present
Co-Founder and President
Engineering consulting firm, based in San Luis Obispo, co-founded with the late Professor F. Owen.
- California Polytechnic State University, San Luis Obispo***, San Luis Obispo, California. 2012-present
Professor of Mechanical Engineering
Associate Professor of Mechanical Engineering
Teaching and research areas include engine and refrigeration system design and analysis, fuels and combustion, wind energy and wind turbine systems design and analysis, heat exchange processes, fluid mechanics. 2007-2012
- Munich University of Applied Sciences (Hochschule München)***, Munich, Germany. 2014-present
Mechanical Engineering Summer School Lecturer; Visiting Professor
Fundamentals of internal combustion engines and associated systems.
- Exponent - Failure Analysis Associates***, Los Angeles, California. 2000-2008
Managing Engineer, Thermal Sciences and Aviation.
Work focused on the investigation of accidents, failures and operation of thermal systems, primarily those concerning reciprocating and gas turbine engines. Performed analyses and laboratory experiments of fundamental design issues where heat transfer, thermodynamics, and fluid mechanics are involved. Example projects included: General Electric aero-derivative steam injected industrial gas turbine engine operating near its design limits; small displacement Honda engine converted to propane; General Motor vehicle converted to natural gas; Fuel Control Units on Pratt-Whitney Canada turboprop engines; natural gas explosion analyses, following leaks in large building structures. A significant aspect of the work required the ability to clearly present and explain complex scientific data and results to clients whose technical expertise did not necessarily extend to the analysis performed.
- Honeywell International***, Torrance, California. 1999-2000
Staff Engineer, Honeywell Aerospace - Performance Analysis Division.
Performed analyses of Environmental Control Systems (ECS), Gas Turbine Engines and Fuel Cells. Developed an analytical model of water-air mixtures for use in the design of Air Cycle Machines. Developed a gas turbine engine performance-modeling program. Assisted in the design and test stages of an automotive Proton Exchange Membrane (PEM) fuel cell.
- IBM Canada Ltd.***, Toronto, Ontario. 1988-1989
Mechanical Engineer Trainee, Manufacturing.
Implemented a new manufacturing process where microchip substrates are mounted directly on printed-circuit boards.

PATRICK LEMIEUX, Ph.D., P.E.

TEACHING EXPERIENCE

ME 302 Thermodynamics I , Professor, Cal Poly. Introductory thermodynamics course. 3 lectures per week.	2014-present
ME 303 Thermodynamics II , Professor, Cal Poly. Intermediate thermodynamics (and terminal course in the Cal Poly thermodynamics curriculum). Covers vapor and gas power cycles, refrigeration cycles, thermodynamic relations, psychrometrics, and chemical reactions. 3 lectures per week.	2014-present
ME 341 Fluid Mechanics I , Professor Cal Poly. Introductory course in undergraduate fluid mechanics. Focuses on fundamental principles such as fluid statics; integral equations for a control volume; introduction to differential analysis of fluid motion; Bernoulli's Equation; dimensional analysis; internal flows. 3 credits.	2009-2012
ME 347 Fluid Mechanics II , Professor Cal Poly. Intermediate course in undergraduate fluid mechanics. Focuses on conservation equations of fluid dynamics, viscous flow, boundary layer concepts, lift and drag, compressible flow, and turbomachinery. Also includes a laboratory (which I did not teach) focused on measurement of turbomachine performance, velocity profiles, and boundary layers. 3 lectures per week.	2014-2015
ME 343 Heat Transfer , Professor, Cal Poly. Fundamental course on engineering heat transfer. Covers all three modes of heat transfer: conduction, radiation and convection. 4 lectures per week.	2012-present
ME 350 Heat Transfer Laboratory , Professor, Cal poly. Laboratory experiments to characterize thermodynamic material properties, energy conversion processes, thermodynamic cycles, and performance of heat transfer equipment. Developed a new laboratory experiment focused on the modeling and verification of the spark ignition (Otto) power cycle. 3 hours per week.	2015-present
ME 422 Introduction to Mechanical Control Systems , Professor, Cal Poly Modeling and control of physical systems. Design of mechanical, hydraulic and electrical systems using time response, frequency response, state space, and computer simulation. 3 hours per week; Also includes a laboratory activity: 3 hours per week.	2018-present
ME 428-429-430 Senior Project Design I-II-III , Professor, Cal Poly. Capstone, project-based class of the Mechanical Engineering program. Acted as both advisor, and sponsor, to several distinct groups. Met weekly with groups of 3-4 students as they go through each step of the design process, facing real-world constraints (such as budget, safety, time management, engineering constraints, communication, teamwork, ethics).	2008-2013
ME 444 Internal Combustion Engines Performance and Design Analysis , Professor, Cal Poly. This senior-level class covers the performance aspects of the design and analysis of reciprocating and gas turbine engines. It carries a large laboratory component, which includes glass combustion chamber engines; a single cylinder, multiple fuels, Cooperative Fuel Research (CFR) engine; several large diesel, gasoline and ethanol engines; and several dynamometers and related engine performance instrumentation. 3 lectures per week, plus 1 laboratory session (3 hours) per week.	2007-present

PATRICK LEMIEUX, Ph.D., P.E.

TEACHING EXPERIENCE (Cont'd)

ME 457 Refrigeration Principles and Design , Professor, Cal Poly. Senior-level technical elective class that presents and studies the most common methods of refrigeration methods found in industry, including multi-staged and cascading vapor cycles, absorption cycles, and reversed Brayton cycles. The laboratory component of the course includes computer modeling of the various systems investigated in class. 4 lectures per week.	2007-2011; 2018
ME 488 Wind Energy Engineering , Professor, Cal Poly. This course focuses on the aerodynamic planform design, analysis, and optimization of horizontal axis wind turbine blades operating at design and off-design conditions. 4 lectures per week.	2009-present
ME 542 Dynamics and Thermodynamics of Compressible Flows (Gas Dynamics) , Professor, Cal Poly. This graduate course presents the fundamental mechanics of compressible flow, from basic principles to the analysis of shock and expansion waves, with specific focus on friction-driven (Fanno) and heat-driven (Rayleigh) flows. 4 lectures per week.	2008-present
Hypersonic Aerodynamics , Teaching Assistant, Caltech. Class covered boundary layers and shock waves in real gases, heat and mass transfer at hypersonic speeds, testing facilities and experiments.	1998
Aircraft Performance and Dynamics , Teaching Assistant, Caltech. Class covered Euler's equations of motion, aircraft stability and control.	1998
Nonsteady Gas Dynamics , Teaching Assistant, Caltech. Class included waves with phase changes and adiabatic flows, and wave interactions in 1D and 2D flows.	1997
Experimental Methods , Teaching Assistant, Caltech. Organized a laboratory class, which included flow visualization techniques (Schlieren and shadowgraph systems) and pressure measurements using Pitot tube traverses. Set up a supersonic wind tunnel for the testing of condensation shocks and the measurements of shock standoff distance on a forward-facing step.	1997
Undergraduate Fluid Mechanics , Teaching Assistant, Caltech.	1994-1995
Systems Control , Teaching Assistant, University of New Brunswick.	1989-1990

SELECTED RESEARCH EXPERIENCE

Rockets and Propulsion: Studied various aspects of hybrid rocket performance (solid fuel and liquid oxidizer); assisted in the development of a laboratory designed to test hybrid rocket motors. Developed novel techniques to improve the use of aerospike nozzles specifically for hybrid rocket motors. Studied the benefits and limitations of using 2-phase oxidizer flows for cooling of rocket parts. Most research supported through NASA STTR program. 1 patent awarded.	2008-present
Wind Power: Developed a research facility for the study of utility-type horizontal axis wind turbine generators. The facility consists of a 3.0 kW HAWT with active yaw control, hydraulic brake system and supervisory control and data acquisition (SCADA) system. The machine will eventually be upgraded to active pitch control. The facility includes a meteorological tower. Patent pending.	2007-present

PATRICK LEMIEUX, Ph.D., P.E.

Internal Combustion Engines: Developed a combined turbocharger-air cycle machine to provide air conditioning in cars and piston-driven airplanes. CAES-enhanced cycles. 3 patent awarded; patents pending. 2007-present

CERTIFICATION or LICENSING

Licensed Mechanical Engineer, M 32617, by the California Board for Professional Engineers and Land Surveyors. 2003-present

EDUCATION

Ph.D., Mechanical Engineering <i>California Institute of Technology</i> , Pasadena, California.	1999
M.Sc., Thermal Power <i>Cranfield University</i> , Bedford, England.	1992
B.Sc.Eng., Mechanical Engineering <i>University of New Brunswick</i> , Fredericton, Canada.	1991

SELECTED PRESENTATIONS

- “Modeling of N₂O Heat Transfer Rates in the Nucleate Boiling Regime, with Experimental Verification” (with Pablo Arribas and Dario Pastrone, Politecnico di Torino), 51st Joint Propulsion Conference, Orlando, Florida, 2015
- “Static Balancing of Small Composite Wind Turbine Rotors”, (with Derek Simon, Cal Poly graduate student), American Wind Energy Association, Windpower2012 Conference, Atlanta, Georgia, June 2012.
- “Development of an Air-Cycle Environmental Control System for Automotive Applications”, Proceedings of the Turbine Technical Conference and Exposition, International Gas Turbine Institute, ASME Turbo Expo, Vancouver, 2011
- “Development of a Reusable Aerospike Nozzle for Hybrid Rocket Motors”, 39th AIAA Fluid Dynamics Conference, San Antonio, 2009 (invited presentation)
- “San Luis Obispo Energy Summit: America’s Renewable Energy Future”, House Republican American Energy Solutions Group, invited panelist and presenter, Spanos Theater, Cal Poly, May 2009
- “Cal Poly Wind Power Research Center: The First Turbine Design Project”, American Wind Energy Association WINDPOWER 2009, Chicago, IL, May 2009
- “The Cal Poly Wind Power Research Center: the Mission, and the First Turbine”, EE 563 Graduate Seminar, Cal Poly, April 2009
- “LPG and Natural Gas Explosions: Case Studies and Examples,” California Conference of Arson Investigators, San Luis Obispo, CA, July 2005 (with A. Reza)
- “An Experimental Investigation of the Instability of Entropy Layers,” Invited Lecture, 12th Annual Liepmann-Ludwig Seminar, Göttingen, Germany, July 1999

PATRICK LEMIEUX, Ph.D., P.E.

SELECTED PUBLICATIONS

Journal Articles

- **Lemieux P**, Fara A, Sanchez P, Murray WR, “Development and Test of an Experimental Apparatus to Study Thermal-Choking in Ideal Gases and Self-Decomposition in Superheated N₂O”, Journal of Energy and Power Engineering, 2014
- **Lemieux P**, Murray WR, Cooke T and Gerhard J “An ‘Inefficient Fin’ Non-Dimensional Parameter to Measure Gas Temperature Efficiently”, NASA Tech Briefs, Vol. 36, No. 5, 2012
- **Lemieux P** “Nitrous Oxide Cooling in Hybrid Rocket Nozzles”, Progress in Aerospace Sciences, V46, Issue 2, 2010
- **Lemieux P**, Hornung HG “Development and Application of Streakline Visualization in Hypervelocity Flow”, Experiments in Fluids, 2002
- Hornung HG and **Lemieux P** “Shock Instability Near the Newtonian Limit Of Hypervelocity Flows,” Physics of Fluids, 2001

Articles Published at Technical Conferences

- JB Cunningham, **Lemieux P** “Study of Low Reynolds Number Effects on Small Wind Turbine Performance”, AIAA 2022-1149, AIAA SCITECH 2022, San Diego, California, 2022
- Ercole G, Garofalo E, **Lemieux P**, Maglie MM, and Pastrone D “N₂O-Cooled Aerospoke for a Hybrid Rocket Motor: Nitrous Oxide Characterization and Additive Manufacturing”, AIAA-2017-4979, 53rd AIAA/SAE/ASEE Joint Propulsion Conference, Atlanta, Georgia, 2017
- **Lemieux P** “Improving the Simple Gas Turbine Cycle with Compressed Air Energy Storage (CAES)”, AIAA-2016-4616, 52nd AIAA/SAE/ASEE Joint Propulsion Conference, Salt Lake City, Utah, 2016
- Arribas PS, **Lemieux P**, Pastrone D “Modeling of N₂O Heat Transfer Rates in the Nucleate Boiling Regime, with Experimental Verification”, AIAA/ASME 51st Joint Propulsion Conference, Orlando, Florida, 2015
- **Lemieux P**, Moore CD and Nahab A “Performance Measurement and Analysis of Vertical Shaft V-Twin Engines, and Comparison with Horizontal Engines of the Same Model Class”, ASME Internal Combustion Engine Division Fall Technical Conference, 2012
- **Lemieux P** and Murray WR, “Nitrous Oxide Cooled, Reusable Hybrid Aerospoke Rocket Motor: Experimental Results”, AIAA/ASME 48th Joint Propulsion Conference, 2012
- Katsanis G and **Lemieux P** “Transient Small Wind Turbine Tower Structural Analysis with Coupled Rotor Dynamic Interaction”, American Wind Energy Association, Windpower2012 Conference, Atlanta, Georgia, June 2012.
- Pastrich D, **Lemieux P** and Owen F “Design of a Safety System for Wind Turbine Tower Tilt-Down Operations” , American Wind Energy Association, Windpower2012 Conference, Atlanta, Georgia, June 2012.
- **Lemieux P**, Moore CD, Gerhardt JG and Dershowitz A “Engine Performance Measurements of Four V-Twin Engines, Using SAE J1349 Correction Factors”, SAE/JSME Small Engine Technology Conference, Sapporo, Japan, 2011
- Grieb JG, **Lemieux P**, Murray WR, Mello JD, Cooke TH and Gerhardt JA “Design and Analysis of a Reusable N₂O-Cooled Aerospoke Nozzle for Labscale Hybrid Rocket Motor Testing”, AIAA 47th Joint Propulsion Conference, San Diego, 2011
- Hornung HG, **Lemieux P**, Kaneshigue M and Valiferdowksi B “Two Effects of High Density Ratio Across Bow Shocks, Part I”, 41st AIAA Fluid Dynamics Conference and Exhibit, Honolulu, 2011 [Note: Paper received ‘2011 Fluid Dynamics Award’]

PATRICK LEMIEUX, Ph.D., P.E.

SELECTED PUBLICATIONS (Cont'd)

- Forster C and **Lemieux P** “Development of an air-cycle environmental control system for automotive applications” , Proceedings of the Turbine Technical Conference and Exposition, ASME Turbo Expo, Vancouver 2011
- **Lemieux P** “Development of a Reusable Aerospike Nozzle for Hybrid Rocket Motors”, 39th AIAA Fluid Dynamics Conference, San Antonio, 2009
- **Lemieux P** and Ridgely JR “Cal Poly Wind Power Research Center”, American Wind Energy Association (AWEA) Windpower Conference, Houston, 2008
- Nosti C, **Lemieux P** and Gascoigne H “Performance Analysis and Life Prediction for Small Wind Turbines: A Wood Laminate Case Study”, American Wind Energy Association (AWEA) Windpower Conference, Houston, 2008
- Katsanis G and **Lemieux P** “Structural Analysis of Small Wind Turbine Towers”, American Wind Energy Association (AWEA) Windpower Conference, Houston, 2008
- **Lemieux P** “High Acceleration Testing for the Mars Microprobe Project”, GALCIT report FM 97-6, Pasadena, California, 1997
- **Lemieux P** “Visualizing the Vorticity Produced by Curved Shocks,” 21st International Symposium on Shock Waves, Great Keppel, Australia, 1997
- Venart JES, **Lemieux P**, Sousa ACM and Tatchell D “The Use of a High Level CFD Code in Engineering Education”, Supercomputing Symposium , Fredericton, Canada, 1991

Technical Reports

- Schroeder S, Slee D and **Lemieux P** “Pfizer Motor Bearing Failure Investigation”, Pfizer Facilities Management and Engineering, San Diego, CA, 2006
- **Lemieux P** “Cause and Origin Investigation of Natural Gas Fire at Pfizer Global Research and Development Laboratories”, Pfizer Facilities Management and Engineering, 2005
- Wade R, **Lemieux P**, Reza A and Deitsch J “Risk Management Plan, Based on EPA Mandated ‘RMP Consequence Analysis’ Guidelines, for the AMPAC In Situ Bioremediation Facility in Henderson Nevada”, AMPAC, 2005
- **Lemieux P** “Transient Pressure and Momentum Balance Failure Analysis in a Two-Phase Flow Geothermal Power Generation Pipeline”, CalEnergy Generation, 2002.
- Martin R, **Lemieux P** and Carnahan R “Supercritical Water Oxidation (SCWO) Reactor Lining Failure Analysis: Corrosion and Thermal Effects”, General Atomics, San Diego, California, 2001
- **Lemieux P** and Martin R “Supercritical Water Oxidation Reactor Failure Mode Analysis: Removable Titanium Liner Prototype”, General Atomics, San Diego, California, 2000
- **Lemieux P** “The Instability of Shear Layers Produced by Curved Shocks,” Ph.D. Thesis, California Institute of Technology, 1999
- **Lemieux P** “High Acceleration Testing for the Mars Microprobe Project”, GALCIT report FM 97-6, Pasadena, California, 1997
- **Lemieux P** “The Aerodynamic Optimization of Wind Turbine Rotors,” M.Sc. Thesis, Cranfield Institute of Technology, Bedford, England, 1992

PATRICK LEMIEUX, Ph.D., P.E.

SELECTED HONORS and AWARDS

- Bently Professor of Mechanical Engineering, California Polytechnic State University, San Luis Obispo, 2010-2014; 2017-2019
- Chrones Professor of Mechanical Engineering, California Polytechnic State University, San Luis Obispo, 2007-2008.
- Exponent 'Excellence Award' for engineering work on the modeling of the World Trade Center, 2002.
- Charles Lee Powell Graduate Fellowship, Caltech, 1997-1998.
- Natural Sciences and Engineering Research Council of Canada PGS-A and PGS-B scholarships for tenure at Caltech, 1992-1996.
- Daniel and Florence Guggenheim Fellowship in Jet Propulsion, 1992-1994.
- Athlone-Vanier Engineering Fellowship, for graduate studies in the U.K. (three awarded per year in Canada), 1991-1992.
- John Stephens Memorial Prize for highest standing in the graduating Mechanical Engineering Class of 1991 at the University of New Brunswick, Canada.

STUDENT AWARDS

- California Polytechnic State University Outstanding Graduate Thesis Award, George Katsanis, June 2014

CREDENTIALS, PROFESSIONAL AFFILIATIONS & OTHERS

- **Associate Fellow:** American Institute of Aeronautics and Astronautics (AIAA)
- Member, Hybrid Rockets Technical Committee, AIAA
- Member: American Society of Mechanical Engineers (ASME); Society of Automotive Engineers (SAE); American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE); American Society of Engineering Educators (ASEE); Aircraft Owners and Pilots Association (AOPA); National Fire Protection Association (NFPA)
- Multi-Engine Land Airplane Private Pilot

PATRICK LEMIEUX, Ph.D., P.E.

MASTER'S STUDENTS ADVISED and CO-ADVISED

Advisor of Record: Thesis Completed

Student Name	Project Title	Completion Date
Niko Banks	System Modeling and Control System Development for Small Windturbine	February 2022
Ethan Narad	Agricultural Wind Fan / Windturbine Optimization	February 2022
Luke Costello	Condition Monitoring and Fault Detection of Blade Damage in Small Wind Turbines Using Time-series and Frequency Analyses	March 2021
John Cunningham	Field Testing the Effects of Low Reynolds Number on the Power Performance of the Cal Poly Wind Power Research Center Small Wind Turbine	December 2020
Eric Griess	Characterization and Optimization of Internal Combustion Engine for Shell Eco-Marathon Americas Challenge	January 30, 2015
George Katsanis	Structural Design of Guy-Wired Wind Turbine Towers	June 2013
Derek Simon	Experimental Performance Benchmarking of the Cal Poly Wind Turbine Rotor	September 2012
Jason Smith	California Polytechnic State University Wind Resource Assessment	September 2011
Lauren Nelson	Rayleigh Flow of Two-Phase Nitrous Oxide as a Hybrid Rocket Nozzle Coolant	May 2010
Christopher Forster	Automotive Air Cycle Machine	November 2009
Bryan Edwards	Composite Manufacturing of Small Wind Turbine Blades	September 2009
Christopher Nosti	Fatigue Life Analysis of Wooden Wind Turbine Blades	July 2009

Advising Committee Member

Student Name	Project Title	Completion Date
Ryan Zhan	Development of Novel Hardware and Software for Wind Turbine Condition Monitoring (Advisor: Prof. J.Ridgely)	March 2021
Daniel Johnson	Design and Implementation of an Indraft Tube Wind Tunnel for the Demonstration of Supersonic Flow Phenomena (Aeronautics)	Jun. 2018
Harrison Sykes	RAMJET Attachment to the Cal Poly Supersonic Wind Tunnel (Aeronautics)	Dec. 2014
Mark Shushnar	A Conceptual Design of a Battery Electric Aircraft Wing (Aeronautics)	June 2014
Tiffany Mitori	Flight and Stability of a Laser Inertial Fusion Energy Target in the Drift Region between Injection and the Reaction Chamber with Computational Fluid Dynamics	Dec. 2013
Jim Keeney	Compressed Air Energy Storage	Nov. 2013
Spenser Lillywhite	Microphone-based Pressure Diagnostics for Boundary Layer Transition	June 2013

PATRICK LEMIEUX, Ph.D., P.E.

MASTER'S STUDENTS ADVISED and CO-ADVISED (Cont'd)

Kent Burnett	A Proposed Control Solution For the Cal Poly Wind Energy Capture System	June 2012
Akane Karasawa	Unsteady Total Pressure Measurement For Laminar-to-Turbulent Transition Detection	July 2011
David Imbaratto	The Interaction between Throttling and Thrust Vectoring of an Annular Aerospike Nozzle	Sept. 2009
Peter Brenen	Simulation of an Oxidizer-Cooled Hybrid Rocket Throat: Methodology Validation for Design of a Cooled Aerospike Nozzle	June 2009
Jason Kempenaar	Transient Liquid-Fuel Penetration under Unsteady In-Cylinder Conditions	July 2007

International Collaboration (Advisor)

Student Name/ Degree Sought	Project Title	International Partner	Completion Date
Antonietta Conte PhD	Advanced Concepts for Rocket Engine Applications	Politecnico di Torino (Polytechnic University of Turin)	Jan 2022
Gaspare Cipolla MSc	Design of Grain Geometry for Constant Thrust in Hybrid Rocket Engine	Politecnico di Torino (Polytechnic University of Turin)	March 2020
Filippo Landi MSc	Regenerative Cooling System	Politecnico di Torino (Polytechnic University of Turin)	March 2020
Giuseppe Quartararo MSc	Design and Test of a Swirling Nitrous Oxide Injection System for a Hybrid Rocket Motor	Politecnico di Torino (Polytechnic University of Turin)	March 2020
Filippo Masseni PhD	Optimization Approaches Under Uncertainty for Hybrid Rocket Engines	Politecnico di Torino (Polytechnic University of Turin)	Feb. 2020
Antonio Avigliano MSc	Improving the gas turbine cycle with CAES	Politecnico di Torino (Polytechnic University of Turin)	Nov. 2017
Margherita Maria Maglie MSc	Analysis of heat transfer modes in post-dry-out N ₂ O	Politecnico di Torino (Polytechnic University of Turin)	April 2017
Erik Garofalo MSc	Experiments on post-dry-out N ₂ O in a Rayleigh Tube	Politecnico di Torino (Polytechnic University of Turin)	April 2017
Giacomo Ercole MSc	Design of Regeneratively Heated Aerospike Nozzle	Politecnico di Torino (Polytechnic University of Turin)	April 2017
Pablo Sanchez MSc	Heat Transfer Aspects of Nitrous Oxide Flow.	Politecnico di Torino (Polytechnic University of Turin)	October 2015

PATRICK LEMIEUX, Ph.D., P.E.

Alberto Fara MSc	The thermo-fluid analysis of nitrous oxide as a coolant in hybrid rocket motors	Politecnico di Torino (Polytechnic University of Turin)	July 2014
Daniel Pastrich BSc	Design of a Safety System for Wind Turbine Tower Tilt-Down Operations	Brandenburg University of Applied Sciences	October 2011
Richard Sandret BSc	Design, implementation and testing of a control system for a small, off-grid wind turbine	Hochschule Karlsruhe-Technik und Wirtschaft Fakultät für Maschinenbau und Mechatronik	August 2010

PROFESSIONAL SERVICE ON CAMPUS

- Chair, Mechanical Engineering Department Peer Review Committee, 2018-20
- Member, hiring committee, Dean of College of Engineering, 2017-18. Result: Hired Amy Fleischer
- Chair, hiring committee, Mechanical Engineering Department position on Renewable energy and nuclear energy. Result: Jacques Bélanger, 2017
- Faculty Hiring Committee 2014-2015
- Retention Promotion Tenure (RPT) committee, Mechanical Engineering Department, 2012-2015
- Faculty Hiring Committee (Bartlett endowed professorship), 2012-2013
- California Polytechnic State University, San Luis Obispo Sustainability Advisory Committee, 2010-2012; 2013-present
- Mechanical Engineering Student Fund Allocation Committee (MESFAC) faculty committee member, 2007-2012
- Graduate Program Committee, 2009-2010
- Mechanical Engineering Curriculum Committee member, 2007-2008
- Mechanical Engineering Department Laboratory Committee, 2007-present

PROFESSIONAL SERVICE OFF CAMPUS

- Diablo Canyon Decommissioning Engagement Panel 2020-2022;
2023-present

Review Committees:

- Aerospace Journal E-ISSN 2226-4310; <https://www.mdpi.com/journal/aerospace> 2019
- Journal of Energy and Power Engineering ISSN 1934-8975, USA 2013-present
- ASME 2013 Internal Combustion Engines Technical Fall Conference 2013

PATRICK LEMIEUX, Ph.D., P.E.

U.S. PATENTS

Granted:

- “System, Method and Apparatus for Improving Gas Turbine Performance with Compressed Air Energy Storage”, U.S. Department of Commerce, U.S. Patent and trademark Office; Pub. No.: US11499477B2, Nov. 2022
- “Air-Cycle Environmental Control Systems and Methods for Automotive Applications”, Patent No.: US 9,249,998 B2, 17 additional claims allowed for Method, Sept. 2017
- “System, Method and Apparatus for Improving Gas Turbine Performance with Compressed Air Energy Storage”, U.S. Department of Commerce, U.S. Patent and trademark Office; Pub. No.: US 2017/0254265 A1, Sept. 2017
- “Air-Cycle Environmental Control Systems and Methods for Automotive Applications”, Patent No.: US 9,249,998 B2, Feb. 2016
- “System, Method and Apparatus for Cooling Rocket Motor Components Using a Saturated Liquid-Vapor Coolant Mixture”, Patent No.: US 8,776,494 B2, Jul. 2014

Pending:

- “Distributed Windturbine LifeLine”, U.S. Department of Commerce, U.S. Patent and trademark Office; Filed Provisional April. 2018

GRANTS and CONTRACTS AWARDED

“SMART Wind Health: Development of an Inexpensive Prognostic Condition Monitoring/Control System for Distributed Wind Turbines”

Sponsor:	U.S. Department of Energy: Office of Science (Phase I STTR)
Award Period:	2017-18
Role:	Principal Investigator
Award Value:	\$150,000

“SMART Wind Consortium: Developing a Consensus-Based Sustainable Manufacturing, Advanced Research and Technology Roadmap for Distributed Wind”

Sponsor:	U.S. Department of Commerce: National Institute of Standards (NIST)
Award Period:	2014-16
Role:	Collaborator and Mechanical Systems Subgroup Leader (Principal Investigator: Distributed Wind Energy Association (DWEA), Flagstaff, AZ)
Award Value:	\$488, 634

PATRICK LEMIEUX, Ph.D., P.E.

GRANTS and CONTRACTS AWARDED (Cont'd)

“A Refined Model for the Behavior of Nitrous Oxide (N₂O) to Assess the Limits of N₂O Cooling”

Sponsor: NASA Small Business Technology Transfer (STTR) Grant, Phase I
Award Period: 2011-12
Role: Investigator (Principal Investigator: WR Murray;
co-Investigators: J.D. Mello and P. Lemieux)
Award Value: \$100k (approx.) [Rolling Hills Research Corp., \$48,000;
Cal Poly, \$52,000]
Students Supported: Terry Cooke (MS – in progress)
Josef Duller (Sr Project, Mech. Eng. – completed)
Owen Raybould (Sr Project, Mech. Eng. – completed)
James Nicovich (Sr Project, Mech. Eng. – completed)

“Sensors and Controls for Cal Poly Wind Power Research Center”

Sponsor: California Central Coast Research Partnership (C3RP)
Award Period: 2011-12
Role: Investigator (Principal Investigator: JR Ridgely)
Award Value: \$31k (approx.)
Students Supported: Daniel Pastrich (BScEng International – Completed)

“Cal Poly Wind Power Research Center: Development and Construction of a Research and Teaching Wind Turbine for Cal Poly”

Sponsor: California Central Coast Research Partnership (C3RP)
Award Period: 2009-11
Role: Principal Investigator
Award Value: \$60k (approx.)
Students Supported: Tom Gwon (MS, JD Mello – completed)
Felicia Knox (CE400, Civil Engineering - completed)
Michael Kulgevich (Sr Project, Mech. Eng. – completed)
Ka-Wah Li (Sr Project, Mech. Eng. – completed)
Alvaro Martinez (Sr Project, Mech. Eng. – completed)
Francisco Martinez (Sr Project, Mech. Eng. – completed)
David Nevarez (Sr Project, Mech. Eng. – completed)
Richard Sandret (MS International – completed)
Travis Robinson-Carter (Sr Project, Mech. Eng. – completed)
Derek Simon (MS – in progress)
Jason Smith (MS – completed)
Zachary Taylor (Sr Project, Mech. Eng. – completed)
Agustin Valverde (CE400, Civil Engineering - completed)

PATRICK LEMIEUX, Ph.D., P.E.

GRANTS and CONTRACTS AWARDED (Cont'd)

“Advanced Fuel Grain Design for Hybrid Rocket Motors”

Sponsor: Workforce Development Award, CA Space Grant Consortium
Award Period: 2011
Role: Investigator (Principal Investigator: W.R. Murray;
co-Investigators: J.D. Mello and P. Lemieux)
Award Value: \$10k (approx.)
Students Supported: Cliff Braun, Matt Parilla
Will Domardt, , Andrew Olson (ME400)

“Hybrid Rocket Motor Design and Testing,”

Sponsor: Lockheed-Martin Corporation
Award Period: 2010-2012
Role: Investigator (Principal Investigator: W.R. Murray;
co-Investigators: J.D. Mello and P. Lemieux)
Award Value: \$10k (approx.)
Students Supported: Cliff Braun, Matt Parilla
Will Domardt, , Andrew Olson (ME400)

“Design, Construction, and Flight Test of a Hybrid Rocket with a Cooled Aerospoke Nozzle”

Sponsor: Workforce Development Award, CA Space Grant Consortium
Award Period: 2010
Role: Investigator (Principal Investigator: W.R. Murray;
co-Investigators: J.D. Mello and P. Lemieux)
Award Value: \$10k (approx.)
Students Supported: Daniel Grieb (MS - completed)
Cliff Braun, Nick Fabino, and James Harper (Senior Project - completed)

GRANTS and CONTRACTS AWARDED (Cont'd)

“A Rayleigh Flow Experiment on Nitrous Oxide (N₂O) to Assess the Limits of N₂O Cooling,”

Sponsor: NASA Small Business Technology Transfer (STTR) Grant,
Phase III
Award Period: 2009-2010
Role: Investigator (Principal Investigator: W.R. Murray;
co-Investigators: J.D. Mello and P. Lemieux)
Award Value: \$70k (approx.) [Rolling Hills Research Corp., \$9,655;
Cal Poly, \$60,345]
Students Supported: Terry Cooke (MS – in progress)
Lauren Nelson (MS – completed)
Peter Brennen (MS – completed)

PATRICK LEMIEUX, Ph.D., P.E.

“A Reusable, Oxidizer-Cooled, Hybrid Aerospike Rocket Motor for Flight Test”

Sponsor: NASA Small Business Technology Transfer (STTR) Grant,
Phase II
Award Period: 2009-11
Role: Investigator (Principal Investigator: W.R. Murray;
co-Investigators: J.D. Mello, P. Lemieux and M. Kerho)
Award Value: \$600k (approx.); [Rolling Hills Research Corp., \$300,000;
Cal Poly, \$300,000]
Students Supported: Terry Cooke (MS – in progress)
Lauren Nelson (MS – completed)
Peter Brennen (MS – completed)

“Design, Construction, and Launch of a Hybrid Rocket”

Sponsor: Lockheed-Martin Corporation
Award Period: 2008-2009
Role: Investigator (Principal Investigator: WR Murray; Investigators: P. Lemieux
and T.W. Carpenter)
Award Value: \$5k (approx.)
Students Supported: Daniel Grieb (MS - completed)
Cliff Braun, Nick Fabino, and James Harper (Senior Project - completed)

“A Reusable, Oxidizer-Cooled, Hybrid Aerospike Rocket Motor for Flight Test”

Sponsor: NASA Small Business Technology Transfer (STTR) Grant,
Phase I
Award Period: 2008-2009
Role: Investigator (Principal Investigator: W.R. Murray; co-Investigators:
T.W. Carpenter, J.D. Mello, and P. Lemieux)
Award Value: \$100k (approx.) [Rolling Hills Research Corp.,
\$42,500; Cal Poly, \$57,500]
Students Supported: Terry Cooke (MS – in progress)
Lauren Nelson (MS – completed)

“Cal Poly Wind Power Research Center: Composite Rotor Development”

Sponsor: California Central Coast Research Partnership (C3RP)
Award Period: 2008
Role: Principal Investigator
Award Value: \$40k (approx.)
Students Supported: Bryan Edwards (MS – completed)

Lemieux

Appendix B

LIST OF MATERIALS CONSIDERED

EXPERT DECLARATION OF DR. PATRICK LEMIEUX, PH.D.

2022-06-02 [001] ¹ Complaint
2022-08-08 [009] LPP Answer and Counterclaim
2022-08-29 [015] GE Answer to LPP Counterclaims
2023-04-03 [037] Joint Claim Construction Chart
2023-04-03 [037-1] App A
2023-04-03 [037-2] App B - M
2023-04-03 [037-3] App N - X
LPP's Opening Claim Construction Brief
US 7,435,080 Prosecution History
US 7,435,080
US 7,770,396 Prosecution History
US 7,770,396
US 7,934,924 Prosecution History
US 7,934,924
First Amended Complaint filed by LPP Combustion, LLC in Case No. 6:21-cv-1343-ADA filed in the Western District of Texas and exhibits attached thereto.
The exhibits attached to my report.
Any other article, book, of other type of material cited to in my report.

¹ Docket numbers, unless indicated otherwise, are in reference to the docket entries of *General Electric Company v. LPP Combustion, LLC*, Civil Action No. 1:22-cv-00720-GBW filed in the District of Delaware.

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Exhibit 1

An
Introduction to

 WILEY

FIRE DYNAMICS

Second Edition



Dougal Drysdale

An Introduction to Fire Dynamics

Second Edition

An Introduction to Fire Dynamics

Second Edition

Dougal Drysdale

University of Edinburgh, UK

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Contents

Preface	xi
List of Symbols and Abbreviations	xiii
1 Fire science and combustion	1
1.1 Fuels and the combustion process	2
1.1.1 The nature of fuels	2
1.1.2 Thermal decomposition and stability of polymers	6
1.2 The Physical chemistry of combustion in fires	11
1.2.1 The ideal gas law	13
1.2.2 Vapour pressure of liquids	16
1.2.3 Combustion and energy release	17
1.2.4 The mechanism of gas phase combustion	23
1.2.5 Temperatures of flames	26
Problems	29
2 Heat transfer	31
2.1 Summary of the heat transfer equations	32
2.2 Conduction	34
2.2.1 Steady state conduction	34
2.2.2 Non-steady state conduction	36
2.2.3 Numerical methods of solving time-dependent conduction problems	44
2.3 Convection	48
2.4 Radiation	52
2.4.1 Configuration factors	57
2.4.2 Radiation from hot gases and non-luminous flames	65
2.4.3 Radiation from luminous flames and hot smoky gases	69
Problems	71
3 Limits of flammability and premixed flames	75
3.1 Limits of flammability	75
3.1.1 Measurement of flammability limits	75
3.1.2 Characterization of the lower flammability limit	79
3.1.3 Dependence of flammability limits on temperature and pressure	82
3.1.4 Flammability diagrams	85
3.2 The structure of a premixed flame	88

3.3	Heat losses from premixed flames	92
3.4	Measurement of burning velocities	97
3.5	Variation of burning velocity with experimental parameters	100
3.5.1	Variation of mixture composition	100
3.5.2	Variation of temperature	102
3.5.3	Variation of pressure	103
3.5.4	Addition of suppressants	103
3.5.5	The effect of turbulence	106
	Problems	107
4	Diffusion flames and fire plumes	109
4.1	Laminar jet flames	111
4.2	Turbulent jet flames	116
4.3	Flames from natural fires	117
4.3.1	The buoyant plume	120
4.3.2	The fire plume	126
4.3.3	Upward flows	135
4.3.4	Interaction of the fire plume with compartment boundaries	136
4.3.5	The effect of wind on the fire plume	144
4.4	Some practical applications	145
4.4.1	Radiation from flames	146
4.4.2	The response of ceiling-mounted fire detectors	149
4.4.3	Interaction between sprinkler sprays and the fire plume	151
4.4.4	The removal of smoke	153
4.4.5	Modelling	154
	Problems	157
5	Steady burning of liquids and solids	159
5.1	Burning of liquids	159
5.1.1	Pool fires	160
5.1.2	Burning of liquid droplets	169
5.2	Burning of solids	172
5.2.1	Burning of synthetic polymers	172
5.2.2	Burning of wood	182
5.2.3	Burning of dusts and powders	190
	Problems	191
6	Ignition: The initiation of flaming combustion	193
6.1	Ignition of flammable vapour/air mixtures	193
6.2	Ignition of liquids	202
6.2.1	Ignition of low flashpoint liquids	207
6.2.2	Ignition of high flashpoint liquids	208
6.3	Pilot ignition of solids	211
6.3.1	Ignition during a continuous heat flux	212
6.3.2	Ignition during a discontinuous heat flux	222

6.4	Spontaneous ignition of combustible solids	227
6.5	Surface ignition by flame impingement	228
6.6	Extinction of flame	229
6.6.1	Extinction of premixed flames	229
6.6.2	Extinction of diffusion flames	230
	Problems	232
7	Spread of flame	233
7.1	Flame spread over liquids	233
7.2	Flame spread over solids	237
7.2.1	Surface orientation and direction of propagation	237
7.2.2	Thickness of the fuel	242
7.2.3	Density, thermal capacity and thermal conductivity	244
7.2.4	Geometry of the sample	245
7.2.5	Environmental effects	246
7.3	Flame spread modelling	255
7.4	Spread of flame through open fuel beds	259
7.5	Applications	259
7.5.1	Radiation-enhanced flame spread	259
7.5.2	Rate of vertical spread	260
	Problems	261
8	Spontaneous ignition within solids and smouldering combustion	263
8.1	Spontaneous ignition in bulk solids	263
8.1.1	Application of the Frank-Kamenetskii model	264
8.1.2	The Thomas model	269
8.1.3	Ignition of dust deposits and oil-soaked lagging	271
8.1.4	Spontaneous ignition in haystacks	274
8.2	Smouldering combustion	275
8.2.1	Factors affecting the propagation of smouldering	276
8.2.2	Transition from smouldering to flaming combustion	284
8.2.3	Initiation of smouldering combustion	285
8.2.4	The chemical requirements for smouldering	287
8.3	Glowing Combustion	288
	Problems	289
9	The pre-flashover compartment fire	291
9.1	The growth period and the definition of flashover	293
9.2	Growth to flashover	296
9.2.1	Conditions necessary for flashover	296
9.2.2	Fuel and ventilation conditions necessary for flashover	305
9.2.3	Factors affecting time to flashover	316
9.2.4	Factors affecting fire growth	321
	Problems	324

10	The post-flashover compartment fire	325
10.1	Regimes of burning	325
10.2	Fully-developed fire behaviour	334
10.3	Temperatures achieved in fully-developed fires	342
10.3.1	Experimental study of fully-developed fires in single compartments	342
10.3.2	Mathematical models for compartment fire temperatures	343
10.4	Fire resistance and fire severity	353
10.5	Methods of calculating fire resistance	360
10.6	Projection of flames from burning compartments	367
10.7	Spread of fire from a compartment	369
	Problems	370
11	The production and movement of smoke	373
11.1	Production and measurement of smoke	375
11.1.1	Production of smoke particles	376
11.1.2	Measurement of particulate smoke	379
11.1.3	Methods of test for smoke production potential	382
11.2	Smoke movement	386
11.2.1	Forces responsible for smoke movement	387
11.2.2	Rate of smoke production in fires	392
11.3	Smoke control systems	396
11.3.1	Smoke control in large spaces	397
11.3.2	Smoke control in shopping centres	399
11.3.3	Smoke control on protected escape routes	400
	References	403
	Answers to Problems	435
	Author Index	439
	Subject Index	447

Table 1.12 Vapour pressures of organic compounds (Weast, 1974/75)

Compound	Formula	<i>E</i>	<i>F</i>	Temperature range (°C)
<i>n</i> -Pentane	<i>n</i> -C ₅ H ₁₂	6595.1	7.4897	-77 to 191
<i>n</i> -Hexane	<i>n</i> -C ₆ H ₁₄	7627.2	7.7171	-54 to 209
Cyclohexane	<i>c</i> -C ₆ H ₁₂	7830.9	7.6621	-45 to 257
<i>n</i> -Octane	<i>n</i> -C ₈ H ₁₈	9221.0	7.8940	-14 to 281
iso-Octane (2,2,4-Trimethyl pentane)		8548.0	7.9349	-36 to 99
<i>n</i> -Decane	<i>n</i> -C ₁₀ H ₂₂	10912.0	8.2481	17 to 173
<i>n</i> -Dodecane	<i>n</i> -C ₁₂ H ₂₆	11857.7	8.1510	48 to 346
Methanol	CH ₃ OH	8978.8	8.6398	-44 to 224
Ethanol	C ₂ H ₅ OH	9673.9	8.8274	-31 to 242
<i>n</i> -Propanol	<i>n</i> -C ₃ H ₇ OH	10421.1	8.9373	-15 to 250
Acetone	(CH ₃) ₂ CO	7641.5	7.9040	-59 to 214
Methyl ethyl ketone	CH ₃ CO.CH ₂ CH ₃	8149.5	7.9593	-48 to 80
Benzene	C ₆ H ₆	8146.5	7.8337	-37 to 290
Toluene	C ₆ H ₅ CH ₃	8580.5	7.7194	-28 to 31
Styrene	C ₆ H ₅ CH = CH ₂	9634.7	7.9220	-7 to 145

Vapour pressures are calculated using the following equation: $\log_{10} p^\circ = (-0.2185E/T) + F$ where p° is the pressure in mm Hg (torr) (Table 1.10), T is the temperature (Kelvin) and E is the molar heat of vaporization. (Note that the temperature range in the table is given in °C.)

where n_A and n_B are the molar concentrations of A and B in the mixture. (These are obtained by dividing the mass concentrations (C_A and C_B) by the molecular weights $M_w(A)$ and $M_w(B)$.) In fact, very few liquid mixtures behave ideally and substantial deviations will be found, particularly if the molecules of A or B are partially associated in the pure state (e.g. water, methanol) or if A and B are of different polarity (Moore, 1972). Partial pressures must then be calculated using the activities of A and B in the solution, thus:

$$p_A = \alpha_A \cdot p_A^\circ \text{ and } p_B = \alpha_B \cdot p_B^\circ \quad (1.17)$$

where

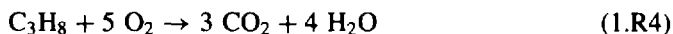
$$\alpha_A = \gamma_A \cdot x_A \text{ and } \alpha_B = \gamma_B \cdot x_B$$

α and γ being known as the activity and the activity coefficient, respectively. The latter is unity for an ideal solution. Values for specific mixtures are available in the literature (e.g. Perry *et al.*, 1984) and have been used to predict the flashpoints of mixtures of flammable and non-flammable liquids from data on flammability limits (Thorne, 1976). However, this will not be pursued further.

1.2.3 Combustion and energy release

All combustion reactions take place with the release of energy. This may be quantified by defining the heat of combustion (ΔH_c) as the total amount of heat released when unit quantity of a fuel (at 25°C and at atmospheric pressure) is oxidized completely. For a hydrocarbon such as propane (C₃H₈) the products would comprise only carbon

dioxide and water, as indicated in the stoichiometric equation:



in which the fuel and the oxygen are in exactly equivalent—or stoichiometric—proportions. The reaction is exothermic (i.e. heat is produced) and the value of ΔH_c will depend on whether the water in the products is in the form of liquid or vapour. The difference will be the latent heat of evaporation of water (44 kJ/mol at 25°C): thus for propane, the two values are:

$$\Delta H_c(\text{C}_3\text{H}_8) = -2220 \text{ kJ/mol}$$

$$\Delta H_c(\text{C}_3\text{H}_8) = -2044 \text{ kJ/mol}$$

where the products are liquid water, and water vapour, respectively. In flames and fires, the water remains as vapour and consequently it is more appropriate to use the latter value.

The heat of combustion of propane can be expressed as either -2044 kJ/mol or $-(2044/44) = -46.45 \text{ kJ/g}$ of propane (Table 1.13) where 44 is the gram molecular weight of C_3H_8 . If the reaction is allowed to proceed at constant pressure, the energy is released as a result of a change in *enthalpy* (ΔH) of the system as defined by Equation (1.R4). However, heats of combustion are normally determined at constant volume in a 'bomb' calorimeter, in which a known mass of fuel is burnt completely in an atmosphere of pure oxygen (Moore, 1972). Assuming that there is no heat loss (the system is adiabatic), the quantity of heat released is calculated from the temperature rise of the calorimeter and its contents, whose thermal capacities are accurately known. The use of pure oxygen ensures complete combustion and the result gives the heat released at constant volume, i.e. the change in the internal energy (ΔU) of the system defined by Equation (1.R4). The difference between the enthalpy change (ΔH) and the internal energy change (ΔU) exists because at constant pressure some of the chemical energy is effectively lost as work done ($P\Delta V$) in the expansion process. Thus, ΔH can be calculated from:

$$\Delta H = \Delta U + P\Delta V \quad (1.18)$$

remembering that for exothermic reactions both ΔH and ΔU are negative. The work done may be estimated using the ideal gas law, i.e.

$$PV = nRT \quad (1.5)$$

where n is the number of moles of gas involved. If there is a change in n , as in Equation (1.R4), then:

$$P\Delta V = \Delta nRT \quad (1.19)$$

where $\Delta n = 7 - 6 = +1$ and $T = 298 \text{ K}$. It can be seen that in this case the correction is small ($\sim 2.5 \text{ kJ/mol}$) and may be neglected in the present context, although it is significant given the accuracy with which heats of combustion can now be measured.

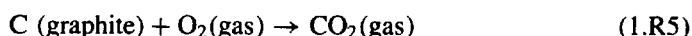
Bomb calorimetry provides the means by which heats of formation of many compounds may be determined. Heat of formation (ΔH_f) is defined as the enthalpy change when a compound is formed in its standard state (1 atmosphere pressure and

Table 1.13 Heats of combustion^a of selected fuels at 25°C (298 K)

		$-\Delta H_c$ (kJ/mol)	$-\Delta H_c$ (kJ/g)	$-\Delta H_{c,air}$ (kJ/g(air))	$-\Delta H_{c,ox}$ (kJ/g(O ₂))
Carbon monoxide	CO	283	10.10	4.10	17.69
Methane	CH ₄	800	50.00	2.91	12.54
Ethane	C ₂ H ₆	1423	47.45	2.96	11.21
Ethene	C ₂ H ₄	1411	50.35	3.42	14.74
Ethyne	C ₂ H ₂	1253	48.20	3.65	15.73
Propane	C ₃ H ₈	2044	46.45	2.97	12.80
<i>n</i> -Butane	<i>n</i> -C ₄ H ₁₀	2650	45.69	2.97	12.80
<i>n</i> -Pentane	<i>n</i> -C ₅ H ₁₂	3259	45.27	2.97	12.80
<i>n</i> -Octane	<i>n</i> -C ₈ H ₁₈	5104	44.77	2.97	12.80
<i>c</i> -Hexane	<i>c</i> -C ₆ H ₁₂	3680	43.81	2.97	12.80
Benzene	C ₆ H ₆	3120	40.00	3.03	13.06
Methanol	CH ₃ OH	635	19.83	3.07	13.22
Ethanol	C ₂ H ₅ OH	1232	26.78	2.99	12.88
Acetone	(CH ₃) ₂ CO	1786	30.79	3.25	14.00
D-Glucose	C ₆ H ₁₂ O ₆	2772	15.4	3.08	13.27
Cellulose	—	—	16.09	3.15	13.59
Polyethylene	—	—	43.28	2.93	12.65
Polypropylene	—	—	43.31	2.94	12.66
Polystyrene	—	—	39.85	3.01	12.97
Polyvinylchloride	—	—	16.43	2.98	12.84
Polymethylmethacrylate	—	—	24.89	3.01	12.98
Polyacrylonitrile	—	—	30.80	3.16	13.61
Polyoxymethylene	—	—	15.46	3.36	14.50
Polyethyleneterephthalate	—	—	22.00	3.06	13.21
Polycarbonate	—	—	29.72	3.04	13.12
Nylon 6,6	—	—	29.58	2.94	12.67

^a The initial states of the fuels correspond to their natural states at normal temperature and pressure (298°C and 1 atm pressure). All products are taken to be in their gaseous state—thus these are the net heats of combustion.

298 K) from its constituent elements, also in their standard states. That for carbon dioxide is the heat of the reaction



where $\Delta H_f^{298}(\text{CO}_2) = -393.5 \text{ kJ/mol}$. The negative sign indicates that the product (CO₂) is a more stable chemical configuration than the reactant elements in their standard states, which are assigned heats of formation of zero.

If the heats of formation of the reactants and products of any chemical reaction are known, the total enthalpy change can be calculated: thus for propane oxidation (Equation (1.R4)):

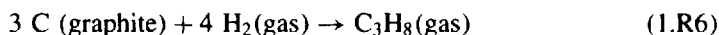
$$\Delta H_c(\text{C}_3\text{H}_8) = 3\Delta H_f(\text{CO}_2) + 4\Delta H_f(\text{H}_2\text{O}) - \Delta H_f(\text{C}_3\text{H}_8) - \Delta H_f(\text{O}_2) \quad (1.20)$$

in which $\Delta H_f(\text{O}_2) = 0$ (by definition). This incorporates Hess' law of constant heat summation, which states that the change in enthalpy depends only on the initial and final states of the system and is independent of the intermediate steps. In fact, $\Delta H_c(\text{C}_3\text{H}_8)$ is

Table 1.14 Standard heats of formation of some common gases

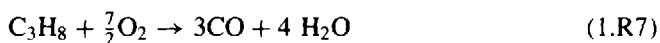
Compound	Formula	ΔH_f^{298} (kJ/mol)
Water (vapour)	H ₂ O	-241.826
Carbon monoxide	CO	-110.523
Carbon dioxide	CO ₂	-393.513
Methane	CH ₄	-74.75
Propane	C ₃ H ₈	-103.6
Ethene	C ₂ H ₄	+52.6
Propene	C ₃ H ₆	+20.7
Ethyne	C ₂ H ₂	+226.9

easily determined by combustion bomb calorimetry, as are $\Delta H_f(\text{CO}_2)$ and $\Delta H_f(\text{H}_2\text{O})$, and Equation (1.20) would be used to calculate $\Delta H_f(\text{C}_3\text{H}_8)$, which is the heat of the reaction

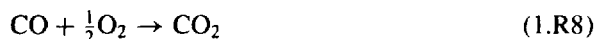


Values of the heats of formation of some common gaseous species are given in Table 1.14. Those species for which the values are positive (e.g. ethene and ethyne) are less stable than the parent elements and are known as endothermic compounds. Under appropriate conditions they can be made to decompose with the release of energy. Ethyne, which has a large positive heat of formation, can decompose with explosive violence.

Values of heat of combustion for a range of gases, liquids and solids are given in Table 1.13: these all refer to normal atmospheric pressure (101.3 kPa) and an ambient temperature of 298 K (25°C) and to complete combustion. It should be noted that the values quoted for ΔH_c are the net heats of combustion, i.e. the product water is in the vapour state. They differ from the gross heats of combustion by the amount of energy corresponding to the latent heat of evaporation of the water (2560 kJ/kg at 100°C). Furthermore, it is not uncommon in fires for the combustion process to be incomplete, i.e. χ in Equation (1.4) is less than unity. The actual heat released could be estimated by using Hess' law of constant heat summation if the composition of the combustion products was known. The oxidation of propane could be written as a two-stage process, involving the reactions:



and



Equation (1.R4) can be obtained by adding together (1.R7) and three times (1.R8). Then by Hess' law

$$\Delta H_{R4} = \Delta H_{R7} + 3\Delta H_{R8} \quad (1.21)$$

where ΔH_{R7} is the heat of reaction (1.R7), $\Delta H_{R4} = \Delta H_c(\text{C}_3\text{H}_8)$ and $\Delta H_{R8} = \Delta H_c(\text{CO})$. As these heats of combustion are both known (Table 1.13), ΔH_{R7} can be shown to be

$$\Delta H_{R7} = 2044 - 3 \times 283 = 1195 \text{ kJ/mol}$$

3

Limits of Flammability and Premixed Flames

In premixed burning, gaseous fuel and oxidizer are intimately mixed prior to ignition. Ignition requires that sufficient energy is supplied in a suitable form, such as an electric spark, to initiate the combustion process which will then propagate through the mixture as a flame (or 'deflagration') (Chapter 1). The rate of combustion is typically high, determined by the chemical kinetics of oxidation rather than by the relatively slow mixing of fuel and oxidizer which determines the structure and behaviour of diffusion flames (Chapter 4). However, before premixed flames are discussed further, it is appropriate to examine flammability limits in some detail and identify the conditions under which mixtures of gaseous fuel and air, or any other oxidizing atmosphere, will burn.

3.1 Limits of Flammability

3.1.1 Measurement of flammability limits

Although it is common practice to refer to gases and vapours such as methane, propane and acetone as 'flammable', their mixtures with air will only burn if the fuel concentration lies within well-defined limits, known as the lower and upper flammability (or 'explosive') limits. For methane, these are 5% and 15% by volume (i.e. molar proportions) respectively. The most extensive review of the flammability of gases and vapours is that of Zabetakis (1965) which, despite its age, remains the standard reference. It is based largely on a collection of data obtained with an apparatus developed at the US Bureau of Mines (Coward and Jones, 1952) (Figure 3.1). Although there are certain disadvantages in this method, these data are considered to be the most reliable that are available. Alternative methods do exist (e.g. Sorenson *et al.*, 1975; Hirst *et al.*, 1981/82), but none has been used extensively enough to provide a challenge to the Bureau of Mines apparatus.

In this method the experimental criterion used to determine whether or not a given mixture is flammable, is its ability to propagate flame. The apparatus, which is shown schematically in Figure 3.1, consists of a vertical tube 1.5 m long and 0.05 m internal

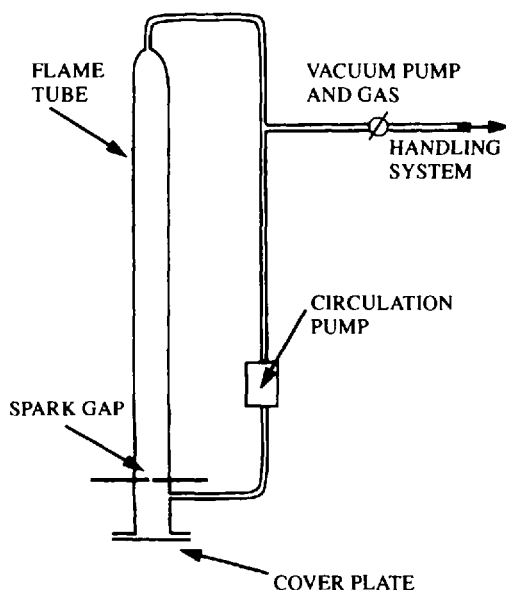


Figure 3.1 The essential features of the US Bureau of Mines apparatus for determining limits of flammability of gases and vapours (Coward and Jones, 1952). (Not to scale.) The circulation pump is necessary to ensure rapid and complete mixing of the gases within the flame tube

diameter, into which premixed gas/air mixtures of known compositions can be introduced. An ignition source, which may be a spark or a small flame, is introduced to the lower end of the tube which is first opened by the removal of a cover plate. The mixture is deemed flammable if flame propagates upward by at least 75 cm. The limits are established experimentally by a process of 'bracketing' and defined as:

$$L = \frac{1}{2}(L_w + L_r) \quad (3.1a)$$

$$U = \frac{1}{2}(U_w + U_r) \quad (3.1b)$$

where L_w and U_r are the greatest and least concentrations of fuel *in air* that are non-flammable, and L_r and U_w are the least and greatest concentrations of fuel in air that are flammable (Zabetakis, 1965). The limits are normally expressed in terms of volume percentage at 25°C although they are functions of temperature and pressure (Section 3.1.3). Flammability limit data are given in a number of publications (Fire Protection Association, 1972; Lewis and von Elbe, 1987; NFPA, 1997) but most can be found in Zabetakis' review (1965) (Table 3.1).

Earlier studies showed that the tube diameter has an effect on the result, although it is small for the lower limit if the diameter is 5 cm or more (Figure 3.2). The closing of the limits in narrower tubes can be explained in terms of heat loss to the wall: indeed, if the diameter is reduced to the quenching diameter, flame will be unable to propagate even through the most reactive mixture (Section 3.3). The limits quoted in the literature (Zabetakis, 1965) refer to upward propagation of flame. These are slightly wider than the limits for downward propagation (Figure 3.2) which may be determined

Table 3.1 Flammability data for gases and vapours

	Lower flammability limit (L) ^a			$\frac{L}{C_u}$	Upper flammability limits (U) ^a			S_u^b (m/s)	Minimum ignition energy ^b (mJ)	Minimum quenching distance ^b (mm)
	% Vol	g/m ³	kJ/m ³		% Vol	g/m ³	$\frac{U}{C_u}$			
Hydrogen	4.0 ^c	3.6	435	0.13	75	67	2.5	3.2	0.01	0.5
Carbon monoxide	12.5	157	1591	0.42	74	932	2.5	0.43	—	—
Methane	5.0	36	1906	0.53	15	126	1.6	0.37	0.26	2.0
Ethane	3.0	41	1952	0.53	12.4	190	2.2	0.44	0.24	1.8
Propane	2.1	42	1951	0.52	9.5	210	2.4	0.42	0.25	1.8
<i>n</i> -Butane	1.8	48	2200	0.58	8.4	240	2.7	0.42	0.26	1.8
<i>n</i> -Pentane	1.4	46	2090	0.55	7.8	270	3.1	0.42	0.22	1.8
<i>n</i> -Hexane	1.2	47	2124	0.56	7.4	310	3.4	0.42	0.23	1.8
<i>n</i> -Heptane	1.05	47	2116	0.56	6.7	320	3.6	0.42	0.24	1.8
<i>n</i> -Octane	0.95	49	2199	0.58	—	—	—	—	—	—
<i>n</i> -Nonane	0.85	49	2194	0.58	—	—	—	—	—	—
<i>n</i> -Decane	0.75	48	2145	0.56	5.6	380	4.2	0.40	—	—
Ethene	2.7	35	1654	0.41	36	700	5.5	>0.69	0.12	1.2
Propene	2.4	46	2110	0.54	11	210	2.5	0.48	0.28	—
Butene-1	1.7	44	1998	0.50	9.7	270	2.9	0.48	—	—
Acetylene	2.5	29	1410	(100)	—	—	—	1.7	0.02	—
Methanol	6.7	103	2141	0.55	36	810	2.9	0.52	0.14	1.5
Ethanol	3.3	70	1948	0.50	19	480	2.9	—	—	—
<i>n</i> -Propanol	2.2	60	1874	0.49	14	420	3.2	0.38	—	—
Acetone	2.6	70	2035	0.52	13	390	2.6	0.50	1.1	—
Methyl ethyl ketone	1.9	62	1974	0.52	10	350	2.7	—	—	—
Diethyl ketone	1.6	63	2121	0.55	—	—	—	—	—	—
Benzene	1.3	47	1910	0.48	7.9	300	2.9	0.45	0.22	1.8

^a Data from Zabetakis (1965). Mass concentration values are approximate and refer to 0°C ($L(\text{g/m}^3) \approx 0.45 M_w L(\text{vol } \%)$).

^b Data from various sources including Kanury (1975) and Lees (1996). There is uncertainty with some of these data (Harris, 1983; Lees, 1996).

^c See Section 3.5.4.

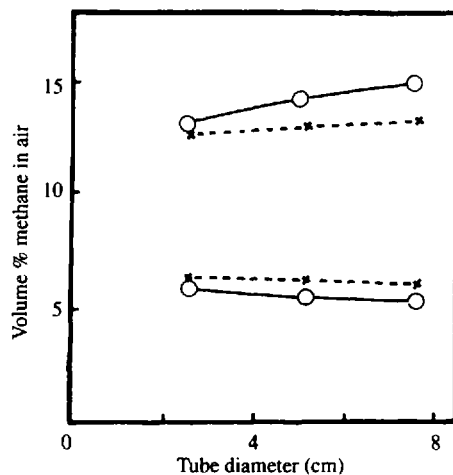


Figure 3.2 Variation of observed flammability limits for methane/air mixtures. ○, upward propagation; ×, downward propagation (Linnett and Simpson, 1957)

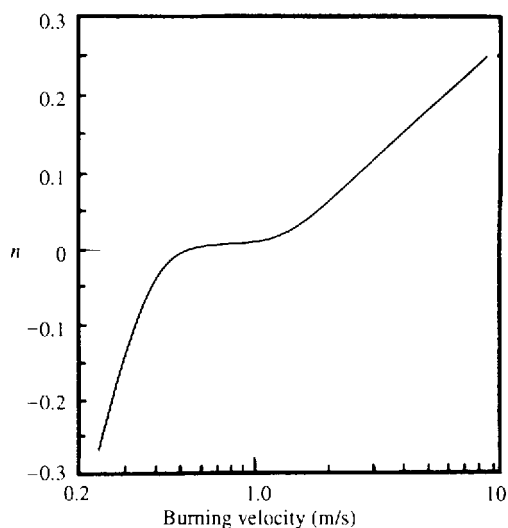


Figure 3.28 Influence of pressure on flame speed (Lewis, 1954; Kanury, 1975). n refers to the exponent in the proportionality $S_u \propto p^n$, where p is the initial pressure

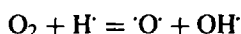
3.5.3 Variation of pressure

There is no simple relationship between burning velocity and pressure. Lewis (1954) assumed that a proportionality of the form $S_u \propto p^n$ would hold, where p is the pressure, and determined the value for n for a range of gases and oxygen concentrations using the spherical bomb method described above. He found that n depended strongly on the value of S_u , being zero for burning velocities in the range 0.45–1.0 m/s (Figure 3.28). For $S_u < 0.45$ m/s, the dependence (i.e. n) is negative, while for $S_u > 1.0$ m/s the dependence is positive. Thus, S_u for methane/air mixtures will decrease with pressure while that for methane/O₂ will increase. Note, however, that the effect is small. Doubling the pressure of a stoichiometric methane/oxygen increases the burning velocity by a factor of only 1.07.

3.5.4 Addition of suppressants

A flammable mixture may be rendered non-flammable by the addition of a suitable suppressant. Additives such as nitrogen and carbon dioxide act as inert diluents, increasing the thermal capacity of the mixture (per unit mass of fuel) and thereby reducing the flame temperature, ultimately to below the limiting value when flame propagation will not be possible (Section 3.1.4). This is illustrated in Figure 3.29(a) which shows the variation of flame temperature, determined by infra-red radiance measurements, as nitrogen is added to stoichiometric methane/air mixtures (Hertzberg *et al.*, 1981). The limiting flame temperature (1500–1600 K) corresponds with 35–38% N₂, in agreement with values calculated on the basis that the lower flammability limit is determined by a critical limiting temperature of this magnitude. Consequently, it is anticipated that the burning velocity at the limit will be similar to that of a limiting methane/air mixture.

However, if chemical inhibitors are present in the unburnt vapour/air mixture, there will be significant reduction in burning velocity without a corresponding reduction in flame temperature. Halogen-containing species are particularly effective in this respect. For example, Simmons and Wolfhard (1955) found that the addition of 2% methyl bromide to a stoichiometric mixture of ethylene and air reduced the burning velocity from 0.66 m/s to 0.25 m/s. These species exert their influence by inhibiting the oxidation chain reactions, reacting with the chain carriers (in particular hydrogen atoms) and replacing them by relatively inert atoms or radicals. As the branching reaction:



is largely responsible for maintaining the high reaction rate (Section 1.2.2), any reduction in hydrogen atom concentration will have a very significant effect on the overall reaction rate. The accompanying heat capacity changes are relatively small so that there is a relatively minor reduction in the flame temperature. This is shown in Figure 3.29(b) in which flame temperature is plotted against concentration of Halon 1301 (bromotrifluoromethane); 4% 1301 is sufficient to render a stoichiometric CH_4/air mixture non-flammable, although the flame temperature at the limit is still high (>1800 K). However, there is some dispute over the interpretation of these data. Hertzberg's experiments involved spark ignition of the gaseous mixtures inside a 3.66 m diameter sphere.

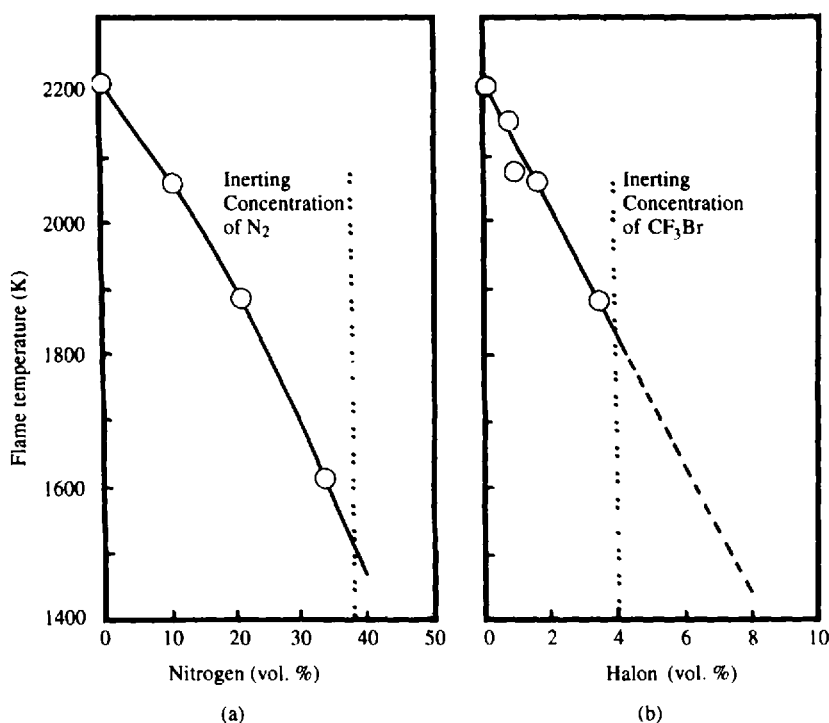


Figure 3.29 Measured premixed flame temperature during explosions in a 3.7 m diameter sphere, stoichiometric methane/air mixtures with addition of (a) nitrogen and (b) CF_3Br (Hertzberg, 1982). Reproduced by permission of University of Waterloo Press

It should be noted that the size and characteristics of the impinging flame are extremely important. A small, laminar flame of low emissivity will transfer heat mainly by convection, but with increasing size and (in particular) thickness, radiation from the flame will come to dominate and the flow may become turbulent. Under these circumstances, the effective heat transfer to the combustible surface can be dramatically increased, causing the surface in contact with the flame to burn vigorously, contributing vapours which will in turn enhance the size of the flame. Taking as an example a vertical surface, such as a combustible wall lining, exposed to a large flame (such as from a burning item of furniture (Williamson *et al.*, 1991)), the heat transfer may be sufficiently great to overcome any ignition resistance that the material may be judged to have on the basis of results from small-scale tests, such as the ISO Ignitability Test, or the Cone Calorimeter. Such data must be interpreted very carefully, bearing in mind the end-use scenario in which the material is to be used. The importance of flame impingement as a means (or source) of ignition has been recognized by the International Organization for Standardization which has examined the characteristics of a wide range of flame sources (ISO, 1997b). (A set of standard ignition sources were developed for testing upholstered furniture in the UK (BSI, 1979).)

6.6 Extinction of Flame

Conceptually, extinction can be regarded as the obverse of pilot ignition and may be treated in a similar fashion, as a limiting condition or criticality. As with pilot ignition, there are two principal aspects to the phenomenon, namely: (i) extinction of the flame, (ii) reducing the supply of flammable vapours to below a critical value ($\dot{m}'' < \dot{m}_{cr}''$).

While the latter will cause the flame to go out, it is possible to achieve (i) without (ii), leaving the risk of re-ignition, which may occur spontaneously with combustible solids and liquids of high flashpoint (e.g. cooking oil) which have been burning for some time. The risk of re-ignition from a pilot will remain until the fuel cools to below its firepoint. However, for gas leaks and low flashpoint liquids, suppression of the flame will leave a continuing release of gaseous fuel which in an enclosed space could lead to the formation of a flammable atmosphere. Under these circumstances, the rate of supply of fuel vapour must be stopped, or at the very least reduced to a non-hazardous level.

6.6.1 Extinction of premixed flames

The stability of premixed flames was discussed in Section 3.3 in relation to the existence of flammability limits. In a confined space, an explosion following the release of a flammable gas can be prevented by creating and maintaining an atmosphere which will not support flame propagation even under the most severe conditions (Section 3.1 and Figure 3.12). This is 'inerting' rather than extinction and must exist before the ignition event occurs in order that flame does not become established. A premixed flame can be extinguished if a suitable chemical suppressant is released very rapidly ahead of the flame front. This is achieved in explosion suppression systems by early detection of the existence of flame, usually by monitoring a small pressure rise within the compartment, and rapid activation of the discharge of the chemical (Bartknecht, 1981; Gagnon,

1997). Typical agents include the halons CF_2Br_2 and CF_2BrCl , as well as certain dry powders (see Section 1.2.4). The halons have been phased out (Section 3.5.4) over the last few years are being replaced by 'ozone-friendly' alternatives. As none of the gaseous substitutes are as effective, there has been much interest in the development of water mist systems (see, e.g., see Brenton *et al.*, 1994; Di Nenno, 1995). Nitrogen and carbon dioxide are suitable only for pre-emptive inerting as the amounts required are too large to be released at the rates necessary for rapid suppression.

Premixed flames may also be extinguished by direct physical quenching. This involves (*inter alia*) cooling the reaction zone and is believed to be the principal mechanism by which a flame arrester operates. This device consists of a multitude of narrow channels, each with an effective internal diameter less than the quenching distance, through which flame cannot propagate. The mechanism is described at some length in Section 3.3(a). Flame arresters are normally installed to prevent flame propagation into vent pipes and ducts in which flammable vapour/air mixtures may form (Health and Safety Executive, 1980; National Fire Protection Association, 1997).

6.6.2 Extinction of diffusion flames

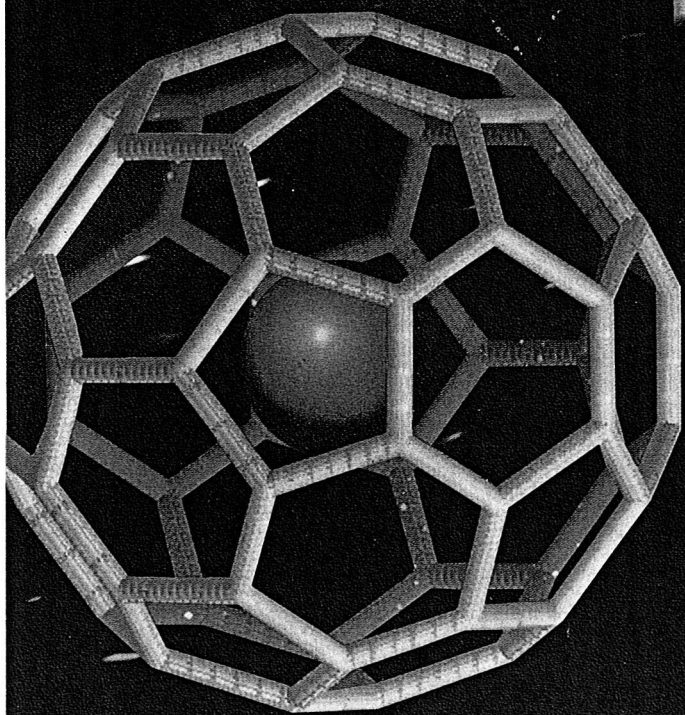
In addition to cutting off the supply of fuel vapours (e.g. closing a valve to stop a gas leak or blanketing the surface of a flammable liquid with a suitable firefighting foam), diffusion flames may be extinguished by the same agents that are used for premixed flames. However, as there are already considerable heat losses from a diffusion flame, theoretically, less agent is required than for premixed flames: in practice, this distinction becomes less significant as the fire size is increased. It is understood that the mechanism by which extinction occurs is essentially the same as in premixed flames. Thus, 'inert' diluents (e.g. N_2 and CO_2) cool the reaction zone by increasing the effective thermal capacity of the atmosphere (per mole of oxygen) (Sections 1.2.5 and 3.5.4) and chemical suppressants such as the halons inhibit the flame reactions (Sections 1.2.4 and 3.5.4).

These agents may be applied locally from hand-held appliances directed at the flame. Small, developing fires are easily extinguished in this way as the local concentration of agent can greatly exceed the minimum requirement. Greater skill is required as the fire size increases, particularly if the supply of agent is limited. All flame must be extinguished before the supply runs out otherwise the fire will simply re-establish itself. This problem can be overcome by 'total flooding', provided that the compartment in which the fire has occurred can be effectively sealed to maintain the necessary concentration of the agent. This is economic only in special circumstances, e.g. when the possibility of water damage by sprinklers is unacceptable, such as in the protection of works of art and valuable documents, and of marine engine rooms and ships' holds. The advantage of chemical suppressants in this role is that the protection system can be activated while personnel are still within the compartment, while prior evacuation is necessary in the case of carbon dioxide (and nitrogen) as the resultant atmosphere is non-habitable. In principle, a halon system can be activated sooner than a CO_2 system, but in addition to the environmental problem, the agent is much more expensive and can generate harmful and corrosive degradation products at unacceptable levels if the fire is already too large when the agent is released. It should be noted that while total flooding may be used to hold in check a deep-seated smouldering fire, it is unlikely to

Lemieux Exhibit 2

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Sixth Edition

On the cover: Representation of a fullerene molecule with a noble gas atom trapped inside. At the Permian-Triassic sedimentary boundary the noble gases helium and argon have been found trapped inside fullerenes. They exhibit isotope ratios quite similar to those found in meteorites, suggesting that a fireball meteorite or asteroid exploded when it hit the Earth, causing major changes in the environment. (Image copyright © Dr. Luann Becker. Reproduced with permission.)

Over the six editions of the Dictionary, material has been drawn from the following references: G. M. Garrity et al., *Taxonomic Outline of the Prokaryotes*, Release 2, Springer-Verlag, January 2002; D. W. Linzey, *Vertebrate Biology*, McGraw-Hill, 2001; J. A. Pechenik, *Biology of the Invertebrates*, 4th ed., McGraw-Hill, 2000; U.S. Air Force Glossary of Standardized Terms, AF Manual 11-1, vol. 1, 1972; F. Casey, ed., *Compilation of Terms in Information Sciences Technology*, Federal Council for Science and Technology, 1970; *Communications-Electronics Terminology*, AF Manual 11-1, vol. 3, 1970; P. W. Thrush, comp. and ed., *A Dictionary of Mining, Mineral, and Related Terms*, Bureau of Mines, 1968; *A DOD Glossary of Mapping, Charting and Geodetic Terms*, Department of Defense, 1967; J. M. Gilliland, *Solar-Terrestrial Physics: A Glossary of Terms and Abbreviations*, Royal Aircraft Establishment Technical Report 67158, 1967; W. H. Allen, ed., *Dictionary of Technical Terms for Aerospace Use*, National Aeronautics and Space Administration, 1965; *Glossary of Stinfo Terminology*, Office of Aerospace Research, U.S. Air Force, 1963; *Naval Dictionary of Electronic, Technical, and Imperative Terms*, Bureau of Naval Personnel, 1962; R. E. Huschke, *Glossary of Meteorology*, American Meteorological Society, 1959; *ADP Glossary*, Department of the Navy, NAVSO P-3097; *Glossary of Air Traffic Control Terms*, Federal Aviation Agency; *A Glossary of Range Terminology*, White Sands Missile Range, New Mexico, National Bureau of Standards, AD 467-424; *Nuclear Terms: A Glossary*, 2d ed., Atomic Energy Commission.

McGRAW-HILL DICTIONARY OF SCIENTIFIC AND TECHNICAL TERMS, Sixth Edition

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inelastic scattering [PHYS] Scattering that results from inelastic collisions. { ,in-ə'las-tik 'skad-ə-riŋ }

inelastic stress [MECH] A force acting on a solid which produces a deformation such that the original shape and size of the solid are not restored after removal of the force. { ,in-ə'las-tik 'stres }

inequality [MATH] A statement that one quantity is less than, less than or equal to, greater than, or greater than or equal to another quantity. { ,in-i'kwäl-əd-ē }

inequality of Clausius See Clausius inequality. { ,in-i'kwäl-əd-ē əv 'klaü-zē-əs }

inequilateral [BIOL] Having the two sides or ends unequal, as the ends of a bivalve mollusk on either side of a line from umbo to gape. { in'ē-kwə'lad-ə-rəl }

inermous [BIOL] Lacking mechanisms for defense or offense, especially spines. { i'nər-məs }

inert [SCI TECH] Lacking an activity, reactivity, or effect. { i'nərt }

inert atmosphere [CHEM ENG] A nonreactive gas atmosphere, such as nitrogen, carbon dioxide, or helium; used to blanket reactive liquids in storage, to purge process lines and vessels of reactive gases and liquids, and to cover a reaction mix in a partially filled vessel. { i'nərt 'at-mə-sfir }

inert gas See noble gas. { i'nərt 'gas }

inert-gas blanketing [ENG] Purging the air from a unit of a heat exchanger by using an inert gas as the unit is being shut down. { i'nərt 'gas 'blan-kəd-iŋ }

inert-gas cutting [MET] Cutting of metal while inert gas flows around the cutting area to prevent oxidation. { i'nərt 'gas 'kəd-iŋ }

inert gas-shielded arc welding [MET] An arc-welding process in which the weld area is shielded by an inert gas to prevent oxidation. Also known as Heliarc welding. { i'nərt 'gas 'shēld-əd 'ärk ,weld-iŋ }

inertia [MECH] That property of matter which manifests itself as a resistance to any change in the momentum of a body. [MED] Sluggishness, especially of muscular activity. { i'nər-shə }

inertia currents [OCEANOGR] Currents resulting after the cessation of wind in a generating area or after the water movement has left the generating area; circular currents with a period of one-half pendulum day. { i'nər-shə ,kə-rəns }

inertia ellipsoid [MECH] An ellipsoid used in describing the motion of a rigid body; it is fixed in the body, and the distance from its center to its surface in any direction is inversely proportional to the square root of the moment of inertia about the corresponding axis. Also known as Poinot ellipsoid. { i'nər-shə i'lip,soid }

inertia governor [MECH ENG] A speed-control device utilizing suspended masses that respond to speed changes by reason of their inertia. { i'nər-shə ,gəv-ə-nər }

inertial circle [METEOROL] A loop in the path of an air parcel in inertial flow, which is approximately circular if the latitudinal displacement is small. Also known as circle of inertia. [OCEANOGR] The circle described by inertial motion in a body of ocean water and having a radius $R = C/f$, where C is the particle velocity in a given direction and f is the Coriolis parameter. { i'nər-shəl ,sər-kəl }

inertial confinement [NUCLEO] The rapid implosion of a high-density pellet, under bombardment by laser or charged-particle beams, to produce a core that is heated to extremely high temperatures before it can fly apart; proposed as a method for generating power from controlled thermonuclear reactions. { in'ər-shəl kən'fin-mənt }

inertial-confinement fusion See pellet fusion. { i'nər-shəl kən'fin-mənt ,fyü-zhən }

inertial coordinate system See inertial reference frame. { i'nər-shəl kō'örd-ən,ət ,sis-təm }

inertial flow [FL MECH] Flow in which no external forces are exerted on a fluid. [GEOPHYS] Frictionless flow in a geopotential surface in which there is no pressure gradient; the centrifugal and Coriolis accelerations must therefore be equal and opposite, and the constant inertial wind speed V_i is given by $V_i = fR$, where f is the Coriolis parameter and R the radius of curvature of the path. { i'nər-shəl 'flō }

inertial force [MECH] The fictitious force acting on a body as a result of using a noninertial frame of reference; examples are the centrifugal and Coriolis forces that appear in rotating

coordinate systems. Also known as effective force. { i'nər-shəl 'förs }

inertial guidance [NAV] 1. Guidance by means of accelerations measured and integrated within the craft. 2. Guidance by the use of an inertial navigation system. { i'nər-shəl 'gīd-əns }

inertial instability [FL MECH] 1. Generally, instability in which the only form of energy transferred between the steady state and the disturbance in the fluid is kinetic energy. 2. The hydrodynamic instability arising in a rotating fluid mass when the velocity distribution is such that the kinetic energy of a disturbance grows at the expense of kinetic energy of the rotation. Also known as dynamic instability. { i'nər-shəl ,in-stə'bil-əd-ē }

inertial mass [MECH] The mass of an object as determined by Newton's second law, in contrast to the mass as determined by the proportionality to the gravitational force. { i'nər-shəl 'mas }

inertial navigation system [NAV] A self-contained system that can automatically determine the position, velocity, and attitude of a moving vehicle by means of the double integration of the outputs of accelerometers that are either strapped to the vehicle or stabilized with respect to inertial space. Also known as inertial navigator. { in'ər-shəl ,nav-ə'gā-shən ,sis-təm }

inertial navigator See inertial navigation system. { i'nər-shəl 'nav-ə,gād-ər }

inertial orbit [ASTRON] The path described by an object that is subject only to gravitational forces, such as a celestial body or a spacecraft that is not under any type of propulsive power. { in'ər-shəl 'ör-bət }

inertial platform [NAV] In an inertial navigator a platform that maintains sensing instruments in a precise known angular orientation in space. { i'nər-shəl 'plat,fōrm }

inertial reference frame [MECH] A coordinate system in which a body moves with constant velocity as long as no force is acting on it. Also known as inertial coordinate system. { i'nər-shəl 'ref-rəns ,frām }

inertial size See aerodynamic size. { i'nər-shəl 'siz }

inertial space [NAV] A coordinate system or frame of reference defined with respect to the stars whose apparent positions relative to surrounding stars appear to be fixed or unvarying for long periods of time. { i'nər-shəl 'spās }

inertia theory [OCEANOGR] The theory associated with the motion of an ocean current under the influences of inertia and the Coriolis force, which cause it to take a circular path. { i'nər-shəl 'thē-ə-rē }

inertia matrix [MECH] A matrix M used to express the kinetic energy T of a mechanical system during small displacements from an equilibrium position, by means of the equation $T = \frac{1}{2} \dot{q}^T M \dot{q}$, where \dot{q} is the vector whose components are the derivatives of the generalized coordinates of the system with respect to time, and \dot{q}^T is the transpose of \dot{q} . { i'nər-shə ,mā-triks }

inertia of energy [RELAT] The principle that the inertial properties of matter both determine and are determined by its total energy content. { i'nər-shə əv 'en-ə-rjē }

inertia period [OCEANOGR] The time required for a given particle to complete an inertia circle. { i'nər-shə ,pir-ē-əd }

inertia starter [MECH ENG] A device utilizing inertial principles to start the rotator of an internal combustion engine. { i'nər-shə 'stārd-ər }

inertia switch [ELEC] A switch that is actuated by an abrupt change in the velocity of the item on which it is mounted. { i'nər-shə ,swich }

inertia tensor [MECH] A tensor associated with a rigid body whose product with the body's rotation vector yields the body's angular momentum. { i'nər-shə ,ten-sər }

inertia wave [FL MECH] 1. Any wave motion in which no form of energy other than kinetic energy is present; in this general sense, Helmholtz waves, barotropic disturbances, Rossby waves, and so forth, are inertia waves. 2. More restrictedly, a wave motion in which the source of kinetic energy of the disturbance is the rotation of the fluid about some given axis; in the atmosphere a westerly wind system is such a source, the inertia waves here being, in general, stable. { i'nər-shə ,wāv }

inertia welding [MET] A form of friction welding which utilizes kinetic energy stored in a flywheel system to supply

needles with a melting point of 2°C and boiling point of 246°C; soluble in alcohol and ether; used in gelatinizing accelerators for pyroxylin. { nī'trāk-sə,lēn }

nitryl halide [INORG CHEM] NO₂X Compound containing a halide (X) and a nitro group (NO₂). { nī'tril 'ha,lid }

nitryl ion See nitronium. { nī'tril ,i,ān }

nival [ECOL] 1. Characterized by or living in or under the snow. 2. Of or pertaining to a snowy environment. { nī-vəl }

nival gradient [GEOL] The angle between a nival surface and the horizon. { nī-vəl ,grād-ē-ənt }

nival surface [GEOL] The hypothetical planar surface containing all of the different snowlines of the same geologic time period. { nī-vəl ,sər-fəs }

nivation [GEOL] Rock or soil erosion beneath a snowbank or snow patch, due mainly to frost action but also involving chemical weathering, solifluction, and meltwater transport of weathering products. Also known as snow patch erosion. { nī'vā-shən }

nivation cirque See nivation hollow. { nī'vā-shən ,sərk }

nivation glacier [HYD] A small, newly formed glacier; represents the initial stage of glaciation. Also known as snow-bank glacier. { nī'vā-shən ,glā-shər }

nivation hollow [GEOL] A small, shallow depression formed, and occupied during part of the year, by a snow patch or snowbank that, through nivation, is thought to initiate glaciation. Also known as nivation cirque; snow niche. { nī'vā-shən ,hāl-ō }

nivation ridge See winter-talus ridge. { nī'vā-shən ,rij }

niveal [GEOL] Property of features and effects resulting from the action of snow and ice. { nīv-ē-əl }

nivenite [MINERAL] UO₂ A velvet-black member of the uranite group; contains rare-earth metals cerium and yttrium; a source of uranium. { nīv-ē,nīt }

niveoglacial [GEOL] Pertaining to the combined action of snow and ice. { nīv-ē-ō'glā-shəl }

niveolian [GEOL] Pertaining to simultaneous accumulation and intermixing of snow and airborne sand at the side of a gentle slope. { nīv-ē-ō'lē-ən }

niveous See niveus. { nīv-ē-əs }

niveus [BIOL] Snow-white in color. Also spelled niveous. { nīv-ē-əs }

Nix Olympica See Olympus Mons. { nīks ə'lim-pə-kə }

NK See natural killer cell.

n-key rollover [COMPUT SCI] The ability of a computer-terminal keyboard to remember the order in which keys were operated and pass this information to the computer even when several keys are depressed before other keys have been released. { 'en ,kē 'rōl-ō-vər }

N-level address [COMPUT SCI] A multilevel address specifying *N* levels of addressing. { 'en ,lev-əl 'ad-res }

N-level logic [ELECTR] An arrangement of gates in a digital computer in which not more than *N* gates are connected in series. { 'en ,lev-əl 'lāj-ik }

NLGI number [ENG] One of a series of numbers developed by the National Lubricating Grease Institute and used to classify the consistency range of lubricating greases; NLGI numbers are based on the American Society for Testing and Materials cone penetration number. { 'en,ljē'ī ,nəm-bər }

N line [SPECT] One of the characteristic lines in an atom's x-ray spectrum, produced by excitation of an *N* electron. { 'en ,līn }

N-m See newton-meter of torque.

N-modular redundancy [COMPUT SCI] A generalization of triple modular redundancy in which there are *N* identical units, where *N* is any odd number. { 'en 'māj-ə-lər ri'dən-dən-sē }

NMOS [ELECTR] Metal-oxide semiconductors that are made on *p*-type substrates, and whose active carriers are electrons that migrate between *n*-type source and drain contacts. Derived from *n*-channel metal-oxide semiconductor. { 'en ,mós }

NMR See nuclear magnetic resonance.

NMRR See normal-mode rejection ratio.

NMR tomography See zeugmatography. { 'en,lēm'ār tə'mäg-rə-fē }

n-net [MATH] A finite net in which *n* lines pass through each point. { 'en ,net }

nn junction [ELECTR] In a semiconductor, a region of transition between two regions having different properties in *n*-type semiconducting material. { 'en,lēn jənk-shən }

nocturnal emission

n-n' reactions See neutron inelastic scattering reactions. { 'en ,n,pīm rē,ak-shənz }

No See nobelium.

no-address instruction [COMPUT SCI] An instruction which a computer can carry out without using an operand from storage. { 'nō 'ad-res in,strək-shən }

no-atmospheric control [AERO ENG] Any device or system designed or set up to control a guided rocket missile, rocket craft, or the like outside the atmosphere or in regions where the atmosphere is of such tenuity that it will not affect aerodynamic controls. { 'nō ,at-mə'sfir-ik kən'trōl }

nobelium [CHEM] A chemical element, symbol No, atomic number 102; a synthetic element, in the actinium series; isotopes with mass numbers 250–260 and 262 have been produced in the laboratory, with mass number 259 having the longest known half-life, 58 minutes. { nō'bel-ē-əm }

noble gas [CHEM] A gas in group 0 of the periodic table of the elements; it is monatomic and, with limited exceptions, chemically inert. Also known as inert gas; rare gas. { 'nō-bəl 'gas }

noble-gas electron configuration [CHEM] An electron structure of an atom or ion in which the outer electron shell contains eight electrons, corresponding to the electron configuration of a noble gas, such as neon or argon. { 'nō-bəl 'gas i'lek,trən kən,fig-yə,rā-shən }

noble metal [MET] A metal, or alloy, such as gold, silver, or platinum having high resistance to corrosion and oxidation; used in the construction of thin-film circuits, metal-film resistors, and other metal-film devices. { 'nō-bəl 'med-əl }

noble potential [PHYS CHEM] A potential equaling or approaching that of the noble elements, such as gold, silver, or copper, of the electromotive series. { 'nō-bəl pə'ten-chəl }

no-bottom sounding [ENG] A sounding in the ocean in which the bottom is not reached. { 'nō 'bād-əm ,saund-īŋ }

no-break power [ELEC] Power system designed to fulfill load requirements during the interval between the failure of the primary power and the time the auxiliary power can be made available. { 'nō 'brāk 'pau-ər }

Nocardiaceae [MICROBIO] A family of aerobic bacteria in the order Actinomycetales; mycelium and spore production is variable. { nō,kār-dē'ās-ē,ē }

nocardiosis [MED] Infection by species of the fungus *Nocardia* characterized by spreading granulomatous lesions. { nō,kār-dē'ō-sēs }

nocerite See fluoborite. { 'nō-sə,rīt }

nociceptive reflex See flexion reflex. { 'nō-sē-ō-ri'sep-tiv 'rē,fleks }

nociceptor [PHYSIO] A sensory nerve ending that is particularly sensitive to noxious stimuli such as chemical changes in surrounding tissue evoked by injury. { 'nō-sə,sep-tər }

noct-, nocti-, nocto-, noctu- [SCI TECH] Combining form meaning night. { nākt, 'nāk-tē, 'nāk-tō, 'nāk-tə }

noctalbuminuria [MED] Excretion of protein in night urine only. { ,nākt-al,byū-mə'nyūr-ē-ə }

Noctilionidae [VERT ZOO] The fish-eating bats, a tropical American monogeneric family of the Chiroptera having small eyes and long, narrow wings. { nākt,til-ē'an-ə,dē }

noctilucent cloud [METEOROL] A cloud of unknown composition which occurs at great heights and high altitudes; photometric measurements have located such clouds between 45 and 54 miles (75 and 90 kilometers); they resemble thin cirrus, but usually with a bluish or silverish color, although sometimes orange to red, standing out against a dark night sky. { 'nāk-təl'it-sənt 'klaüd }

noctiphobia [PSYCH] Abnormal fear of night or darkness. { ,nāk-tə'fō-bē-ə }

Noctuidae [INV ZOO] A large family of dull-colored, medium-sized moths in the superfamily Noctuoidea; larva are mostly exposed foliage feeders, representing an important group of agricultural pests. { nākt'it-ə,dē }

Noctuoidea [INV ZOO] A large superfamily of lepidopteran insects in the suborder Heteroneura; most are moderately large moths with reduced maxillary palpi. { nākt'it-ō'id-ē-ə }

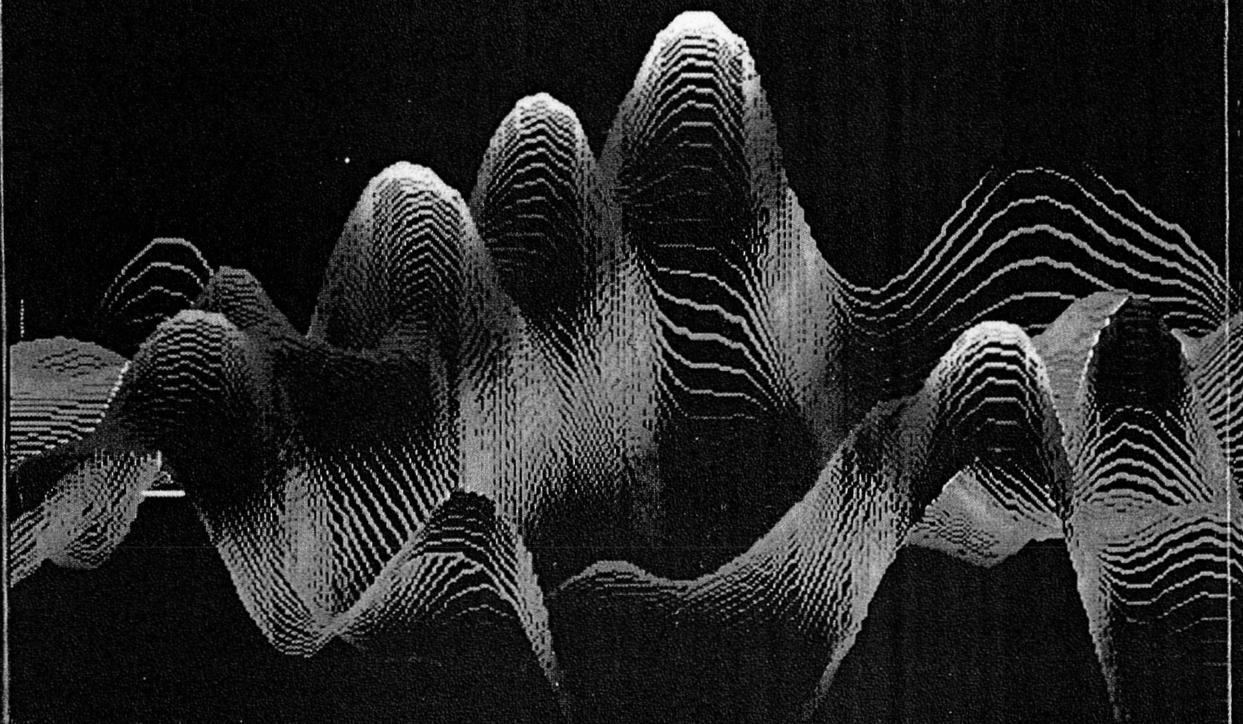
nocturia [MED] Excessive urination at night. { nāk'tūr-ē-ə }

nocturnal [BIOL] Active during the nighttime. [SCI TECH] Occurring during the nighttime. { nākt'əm-əl }

nocturnal emission [PHYSIO] Normal, involuntary seminal

Lemieux Exhibit 3

CHAMBERS DICTIONARY OF SCIENCE AND TECHNOLOGY



UNRIVALLED COVERAGE OF
MODERN SCIENTIFIC TERMS

CHAMBERS

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induration (*Geol*) The process of hardening a soft sediment by heat, pressure and cementation. Cf **diagenesis**.

induration (*Med*) Hardness. Often used to describe tumours.

Indus (*Indian*) (*Astron*) An inconspicuous southern constellation.

indusium (*Zool*) In some insects, a third embryonic envelope lying between the chorion and the amnion in the early stages of development of the egg; a cerebral convolution of the brain in higher vertebrates; an insect larva case. Adjs *indusiate*, *indusiform*.

industrial design (*Genri*) Methods used to plan and market products, with special emphasis on external shape and form (eg ergonomics). Complementary to engineering design. See **product design**.

industrial diamond (*Min*) Small diamonds, not of gemstone quality, eg **black diamond** and **bort**; used to cut rock in borehole drilling, and in abrasive grinding. Now synthesized on a considerable scale by subjecting carbon to ultra-high pressures and temperature.

industrial frequency (*ElecEng*) A term used to denote the frequency of the alternating current used for ordinary industrial and domestic purposes, usually 50 or 60 Hz. Also *mains* or *power frequency*.

industrial melanism (*Ecol*) Melanism which has developed as a response to blackening of trees and other habitats by industrial pollution. This favours melanic forms, esp among moths which rest on trees during the day.

industry standard architecture (*Comp*) A standard architecture for IBM-compatible computers.

inelastic collision (*Phys*) In atomic or nuclear physics, a collision in which there is a change in the total energies of the particles concerned resulting from the excitation or de-excitation of one or both of the particles. See **collision**.

inelastic scattering (*Phys*) See **scattering**.

inequality (*Astron*) The term used to signify any departure from uniformity in orbital motion; it may be *periodic*, ie completing a full cycle within a specific time and then repeating it or *secular*, ie increasing steadily in magnitude with time.

inequality (*Maths*) A statement as to which is the larger or smaller of two quantities. The statement that *a* is larger than *b* is written $a > b$, and the consequential statement that *b* is smaller than *a*, $b < a$. The inequality sign, $>$ or $<$, can be coupled with the equality sign, $=$, and is then written \geq or \leq .

inequiptent (*Zool*) Possessing different potentialities for development and differentiation.

inequivalve (*Zool*) Having the two valves of the shell unequal.

inert (*Chem*) Not readily changed by chemical means.

inert anode (*Ships*) An anode of platinized titanium, used in **cathodic protection**. Requires an impressed direct current. Long-lasting. Cf **virtually inert anode**.

inert gases (*Chem*) See **noble gases**.

inertia (*ImageTech*) A factor used in some systems of photographic speed rating, obtained by extrapolating the linear portion of the **characteristic curve** to indicate the nominal exposure for zero density.

inertia (*Phys*) The property of a body, proportional to its mass, which opposes a change in the motion of the body. See **inertial force**, **inertial reference frame**.

inertia governor (*Eng*) A shaft type of centrifugal governor using an eccentrically pivoted weighted arm, which responds rapidly to speed fluctuations by reason of its inertia, and in such a way as to suppress them.

inertial confinement (*NucEng*) In fusion studies, short-term plasma confinement arising from inertial resistance to outward forces (mainly by the compression and heating of deuterium or mixed deuterium-tritium pellets by a powerful laser). See **containment**, **inertial fusion system**, **magnetic confinement**.

inertial damping (*Phys*) Damping which depends on the acceleration of a system, and not velocity.

inertial force (*Phys*) An apparent force resulting from the use

of accelerating and rotating frames of reference. Newton's laws may still be used in these frames if inertial forces are introduced to preserve the second law of motion. In the case of rotating frames these forces are the centrifugal and Coriolis forces.

inertial fusion system (*NucEng*) System in which small capsules (*pellets*) containing deuterium and tritium are injected into a reaction chamber and ignited by high energy laser or ion beams. See **magnetic confinement fusion system**.

inertial guidance (*Aero*) Navigation of a aircraft, spacecraft or missile by measuring the inertial forces during flight and comparing them with a program held on board. It is not subject to outside interference.

inertial impaction (*PowderTech*) Method of collecting small particles of dust and droplets from a fluid stream by allowing them to impinge upon an interposed deflecting surface.

inertial navigation system (*Aero*) An assembly of highly accurate gyros to stabilize a platform supported on gimbals on which are mounted a group of similarly accurate accelerometers (typically one for each of the three rectilinear axes) which measure all accelerations imparted. With one automatic time integration, these measurements give a continuous read-out of velocity and with another a read-out of present position related to the start. Accuracy is typically one in 10^9 . See **fibre-optics gyro**.

inertial reference frame (*Phys*) In mechanics, a reference frame in which Newton's first law of motion is valid.

inertia switch (*ElecEng*) One operated by an abrupt change in its velocity, as for some meters, to avoid overloading.

inertia wheel (*Space*) See **momentum wheel**.

inertinite (*Geol*) A carbon-rich **maceral** found in coal.

inert metal (*Phys*) Alloy (usually Ti-Zr) for which scattering of neutrons by nuclei is negligible.

I neutron (*Phys*) A neutron possessing such energy as to undergo resonance absorption by iodine.

infant food (*FoodSci*) Food formulated and produced under rigorous controls to ensure optimum nutritional requirements, freedom from microbiological contamination and ready assimilation. Designed for the transition from breast feeding to unaided eating and to give a range of textures and tastes.

infanticide (*Med*) Killing of an infant, particularly the killing of a newborn infant by its mother.

infantile paralysis (*Med*) See **poliomyelitis**.

infantilism (*Med*) A disturbance of growth, the persistence of infantile characters being associated with general retardation of development.

infarct (*Med*) That part of an organ which has had its blood supply cut off, the area so deprived undergoing aseptic necrosis.

infarction (*Med*) The formation of an **infarct**; the infarct itself.

infection (*Med*) The invasion of body tissue by living micro-organisms, with the consequent production in it of morbid change; a diseased condition caused by such invasion; the infecting micro-organism itself.

infectious anaemia of horses (*Vet*) An acute or chronic RNA viral disease of equines spread by biting insects and other mechanical vectors. Symptoms include pyrexia, depression, oedema and anaemia. Virus found in all tissues and persist in **white blood cells** for life. Vaccines available. Notifiable in the UK. Also *swamp fever*.

infectious avian bronchitis (*Vet*) An acute, highly contagious respiratory disease of chickens, caused by a virus and associated with inflammation of the respiratory tract, esp the trachea and bronchi; the main symptoms are nasal discharge, gasping, rales and coughing.

infectious avian encephalomyelitis (*Vet*) An encephalomyelitis of young chicks, caused by a virus, and characterized by muscular inco-ordination, muscular tremor and death. Also *epidemic tremor*.

infectious bovine rhinotracheitis (*Vet*) Common herpes

glycerine with a cold mixture of concentrated nitric and sulphuric acids. It solidifies on cooling, and exists in two physical crystalline modifications. In thin layers it burns without explosion, but explodes with tremendous force when heated quickly or struck. See **dynamite**, **explosive**. Used medically in solution and tablets for angina.

Nitrolime (Chem) TN for an artificial fertilizer consisting of calcium cyanamide.

nitromethane (Chem) CH_3NO_2 . Bp $99^\circ\text{--}101^\circ\text{C}$. A liquid prepared from chloroacetic acid and sodium nitrate.

nitrophilous (Bot) Plants growing characteristically in places where there is a good supply of fixed nitrogen.

nitroprussides (Chem) Formed by the action of nitric acid on either hexacyano ferrates (II) or (III). The nitroprusside ion is $[\text{Fe}(\text{CN})_5]^-$. Also *nitrosoferricyanides*.

nitrosamine (FoodSci) Compound produced by the reaction of nitrates and nitrites with primary and secondary amines under mildly acid conditions. There is evidence that such compounds could be carcinogenic.

nitroso compounds (Chem) Compounds containing the monovalent radical $-\text{NO}$.

nitroso-dyes (Chem) Dyestuffs resulting from reaction between phenols and nitrous acid.

nitrosoferricyanides (Chem) See **nitroprussides**.

nitrotoluenes (Chem) $\text{CH}_3\text{C}_6\text{H}_4\text{NO}_2$. On nitration of toluene a mixture of 2- and 4-nitrotoluene is obtained with very little 3-nitrotoluene. 2-Nitrotoluene, a liquid, has a bp 218°C ; 4-nitrotoluene crystallizes in large crystals; mp 54°C , bp 230°C .

nitrous [nitric (III)] acid (Chem) The pale-blue unstable solution obtained by precipitating barium nitrite with dilute sulphuric acid is supposed to contain nitrous acid, HNO_2 .

nitrous oxide (Chem) Laughing gas, N_2O . A colourless gas with a sweetish odour and taste, soluble in water, alcohol, ether and benzene. Nitrous oxide supports combustion better than air. The gas is manufactured by the decomposition of ammonium nitrate by heat. It is used for producing anaesthesia of short duration.

nitroxyl (Chem) The radical $-\text{NO}_2$ when attached to a halogen atom or a metal. Compounds containing the group are *nitroxyls*.

nitroization (Biol, Bot) The conversion of ammonia into nitrites by the action of soil bacteria (*Nitrosomonas*), being the second stage in the nitrification in the soil.

Nivarox (Eng) Alloy of iron and nickel with a small addition of beryllium, non-magnetic, rustless and of controllable elasticity, used for hairsprings.

NK cell (Immun) Abbrev for **natural killer cell**.

NLM (Comp) Abbrev for **Network loadable module**. A program stored on a **file server** operating a **LAN** under **Novell Network**. The module provides extra or advanced facilities to the network and its users.

nm (Genrl) Abbrev for **nanometre** $= 10 \text{ \AA} = 10^{-9} \text{ m}$.

NMDA (Biol) Abbrev for **N-methyl-D-aspartic acid**.

N-methyl-D-aspartic acid (Biol) An agonist for a class of **glutamate receptor** (NMDA-receptor) found on some vertebrate nerve cells. Abbrev **NMDA**.

NMOS (Electronics) **Metal-oxide-silicon** technology based on n-channel devices in a p-type substrate.

NMR (Chem, Phys) Abbrev for **nuclear magnetic resonance**.

NMR spectroscopy (Chem) Abbrev for **nuclear magnetic resonance spectroscopy**.

nn, n-n heterojunction (Electronics) A junction in a **heterostructure** formed between a narrower band gap material (n-type) and a wider gap material (N-type).

nn, n-n junction (Electronics) A junction formed within a n-type semiconductor where the donor dopant concentration changes abruptly.

No (Chem) Symbol for **nobelium**.

NOAA (Space) Abbrev for **National Oceanic and Atmospheric Administration**, a US body which manages and operates environmental satellites, and provides data to users worldwide.

nobelium (Chem) Man-made element. At no 102; symbol **No**. Principal isotope is 254.

noble gases (Chem) Elements helium, neon, argon, krypton, xenon and radon-222, much used (except the last) in gas-discharge tubes. (Radon-222 has short-lived radioactivity, half-life less than four days.) Their outer (valence) electron shells are complete, thus rendering them inert to all the usual chemical reactions; a property for which argon, the most abundant, finds increasing industrial use. The heavier ones, Rn, Xe, Kr, are known to form a few unstable compounds, eg XeF_4 . Also *inert gases*, *rare gases*.

noble metals (Eng) Metals, such as gold, silver, platinum etc which have a relatively positive electrode potential, and which do not enter readily into chemical combination with non-metals. They have high resistance to corrosive attack by acids and other agents, and resist atmospheric oxidation. Cf **base metal**.

nocardiosis (Med) Infection (usually of the lungs) with any one of a number of spore-forming fungi of the genus *Nocardia*.

nociceptive (Zool) Sensitive to pain.

noctilucous (Zool) Phosphorescent; light producing.

noctilucous clouds (Meteor) Thin but sometimes brilliant and beautifully coloured clouds of dust or ice particles at a height of 75-90 km. They are visible about midnight in latitudes greater than about 50° when they reflect light from the Sun below the horizon.

Noctovision (ImageTech) TN for a system of television in which the light sensitive elements respond to infrared light, and which can therefore be operated in darkness.

nocturia (Med) Passing excessive quantities of urine at night.

nodal gearing (Eng) The location of gear wheels, eg between a turbine and propeller shaft, at a nodal point of the shaft system with respect to torsional vibration.

nodal point (Telecomm) (1) Point in a high frequency circuit where current is a maximum and voltage a minimum, or vice versa. (2) In electrical networks, a terminal common to two or more branches of a network or to a terminal of any branch. Also *node*.

nodal points of a lens (Phys) Two points on the principal axis of a lens or lens system such that an incident ray of light directed towards one of them emerges from the lens as if from the other, in a direction parallel to that of the incident ray. For a lens having the same medium on its two sides, the nodal points coincide with the principal points.

node (Astron) One of the two points at which the orbit of a celestial object intersects a reference plane, such as the **ediptic** or **celestial equator**. The path crossing from south to north is the **ascending node**; **descending node** has the opposite sense.

node (Bot) The position on a stem at which one or more leaves are attached. Cf **internode**.

node (Comp) (1) A data item within a **tree data structure**. (2) A point at which two or more communications lines meet. The term is usually applied to the switching device or computer which is situated at this point.

node (ElecEng) (1) Point of minimum disturbance in a system of waves in tubes, plates or rods. The amplitude cannot become zero, otherwise no power could be transmitted beyond the point. (2) Point in an electrical network where two or more conductors are connected.

node (Eng) (1) A point, or more than one, of rest in vibrating body. (2) A junction point of two or more members in a structural frame.

node (Maths) See **double point**.

node (Phys) See **antinode**.

node (Telecomm) See **nodal point**.

nodes of Ranvier (Zool) Constrictions of the neurolemma occurring at regular intervals along medullated nerve fibres. See fig. at **neurone**.

node voltage (Telecomm) That of a **nodal point** in an electrical network.

nodose, nodular (Bot) Bearing localized swellings or nodules.

Lemieux Exhibit 4

Webster's II

New College Dictionary

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for which the proposition is assumed to be correct. 4. The act of inducing. 5. Archaic. A preface or prologue esp. to a literary composition.

induction coil *n.* A transformer, often used in automotive ignition systems, in which an interrupted, low-voltage direct current in the primary is changed into an intermittent, high-voltage current in the secondary.

in-due-tive (in-dûk'tiv) *adj.* 1. Of, pertaining to, or utilizing induction <the inductive process>. 2. Elect. Of or resulting from induction <inductive reactance>. 3. Causing or influencing: INDUCING. 4. Introductory. — **in-due-tive-ly** *adv.* — **in-due-tive-ness** *n.*

inductive statistics *n.* (sing. in number). The branch of statistics dealing with generalizations, predictions, estimations, and decisions from data initially presented.

in-duc-tor (in-dûk'tôr) *n.* 1. One that inducts. 2. Elect. A device that functions by or introduces induction into a circuit.

in-due (in-dûo', -dûo'v) *v.* var. of **ENDUE**.

in-dulge (in-dûl'j) *v.* -**dulged**, -**dulging**, -**dulges**. [Lat. *indulgere*, to be kind.] — *vt.* 1. To accede to the desires and whims of, esp. to an excessive degree: HUMOR. 2. a. To yield to: GRATIFY <indulge their desire for a new car>. b. To allow (oneself) unrestrained gratification. 3. To grant an ecclesiastical indulgence or dispensation to. — *vi.* To indulge oneself. — **in-dulger** *n.*

in-dul-gence (in-dûl'jans) *n.* 1. The act of indulging or state of being indulgent. 2. Something indulged in <a season tickled at the opera is an expensive indulgence>. 3. Something granted as a favor or privilege. b. Remission to extend the time of payment or performance. 4. Liberal or lenient treatment: TOLERANCE. 5. Rom. Cath. Ch. The remission of punishment still due for a sin that has been sacramentally absolved. — *vt.* -**genced**, -**gencing**, -**gences**. Rom. Cath. Ch. To attach an indulgence to.

in-dul-gent (in-dûl'jant) *adj.* Displaying, marked by, or given to indulgence: LENIENT. — **in-dul-gent-ly** *adv.*

in-dult (in-dûlt') *n.* [ME < Med. Lat. *indultum* < Lat. *indultus*, p.p.t. of *indulgere*, to be kind.] Rom. Cath. Ch. A usu. temporary dispensation.

in-du-pli-cate (in-dûo'pli-kt, -dûo'v) *adj.* [in- & Lat. *duplicatus*, doubled. — *see* **DUPLICATE**.] Bot. With the edges turned or folded inward.

in-du-rate (in-dô-rat', -dya) *v.* -**rated**, -**rating**, -**rates**. [Lat. *indurare*, *indurat-* (in- (intensive) & *durus*, hard)] — *vt.* 1. To make hard. 2. To make hard. 3. To make callous. — *vi.* 1. To harden. 2. To become firmly established or fixed. — *adj.* (in-dû-rat', -dya). Obstinate: UNFLEXING. — **in-du-ra-tion** *n.* — **in-du-ra-tive** *adj.*

in-dus-tri-al (in-dûo'zê-am, -zhê-, -dûo'v) *n.* pl. -**si-a** (-zê-a, -zhê-a) [Lat., tunic < *inducere*, to put on.] An enclosing membrane, as that covering the sorus of a fern.

in-dus-tri-al (in-dûs'tri-âl) *adj.* 1. Of, relating to, or derived from industry. 2. Having highly developed industries <an industrial culture>. 3. Employing, necessary, or used in industry <industrial machinery>. — *n.* 1. One employed in industry. 2. An industrial firm. 3. A stock or bond issued by an industrial enterprise.

industrial arts *pl. n.* (sing. in number). A subject of study in schools aimed at developing manual and technical skills for working with machinery or tools.

in-dus-tri-al-ism (in-dûs'tri-âl-iz'm) *n.* A system in which industries are dominant. — **in-dus-tri-al-ist** *n.*

in-dus-tri-al-ize (in-dûs'tri-âl-iz') *v.* -**ized**, -**izing**, -**izes**. — *vt.* To cause to be or become industrial. — *vi.* To become industrial. — **in-dus-tri-al-iza-tion** *n.*

industrial park *n.* An area usu. situated on the outskirts of a city and zoned for a group of industries and businesses.

industrial psychology *n.* Psychology applied to problems of industry, as personnel selection, training, and efficiency. — **industrial psychologist** *n.*

industrial revolution *n.* often **Industrial Revolution**. Radical social and economic changes, as those in late 18th-cent. England, brought about when extensive mechanization of production systems results in a shift from home-based manufacturing to large-scale factory production.

industrial union *n.* A labor union to which all the workers of a particular industry can belong regardless of their trade.

in-dus-tri-ous (in-dûs'tri-ôs) *adj.* 1. Diligently active: ASSIDUOUS. 2. Obs. Skillful and clever. — **in-dus-tri-ous-ly** *adv.* — **in-dus-tri-ous-ness** *n.*

in-dus-try (in-dûs'tre) *n.*, pl. -**tries**. [ME *industrie*, skill < OFr. < Lat. *industria*, diligence.] 1. The commercial production and sale of goods and services. 2. A particular branch of manufacture and trade <the electronics industry>. 3. Industrial management as distinguished from labor. 4. Diligence: assiduity.

in-dwell (in-dwêl') *v.* -**dwelt** (-dwêlt'), -**dwell-ing**, -**dwells**. — *vi.* To exist as an energizing inner spirit, force, or principle <creative powers indwelling throughout the world>. — *vt.* To reside within as an energizing spirit, force, or principle. — **in-dwell'er** *n.*

in-dwell-ing (in-dwêl'ing) *adj.* Med. Left within a bodily organ or passage, esp. to facilitate drainage <an indwelling catheter>.

— **in-e'** suff. [ME < OFr. -in, partly < Lat. -inus, adj. suffix, and partly

< Lat. -inus < Gk. -inos, adj. suffix.] 1. Of or relating to <Benedictine>. 2. Made of: RESEMBLING <opaline>.

— **in-e'** suff. [Fr. < Lat. -ina, fem. of -inus, of or belonging to.] 1. A chemical substance <azine>. 2. Halogen <bromine>. 3. or -in. Alkaloid <quinine>. 4. A mixture of compounds <gasoline>. 5. Commercial material <glassine>. 6. var. of -in-1.

in-e-bri-ant (in-ê-brê-ant) *adj.* Intoxicating. — *n.* An intoxicant.

in-e-bri-ate (in-ê-brê-ât') *vt.* -**ated**, -**ating**, -**ates**. [Lat. *inebriare*, *inebriat-* (in- (intensive) & *ebriare*, to intoxicate < *ebrius*, drunk).] 1. To make drunk: INTOXICATE. 2. To stupefy or exhilarate as if with alcohol. — *adj.* (in-ê-brê-ât'), intoxicated. — *n.* (in-ê-brê-ât'), an intoxicated person, esp. a drunkard. — **in-e-bri-a-tion** *n.*

in-e-bri-ety (in-ê-brê-ê-tê) *n.* Intoxication: drunkenness.

in-e-dif-fi-ble (in-êd'fâ-bul) *adj.* Not edible.

in-e-dif-fi-ble (in-êd'fâ-bul) *adj.* [ME < OFr. < Lat. *ineffabilis*: in- (not) & *effabilis*, utterable < *effari*, to utter (ex-, out & *fari*, to speak).] 1. Beyond expression: INDESCRIBABLE <ineffable happiness>. 2. Not to be uttered: TABOO <the ineffable name of God>. — **in-e-dif-fi-bil-ity**, **in-e-dif-fi-bil-ness** *n.* — **in-e-dif-fi-bly** *adv.*

in-e-dif-fi-able (in-êd'fâ-sâ-bul) *adj.* Not effaceable: INDELEIBLE. — **in-e-dif-fi-abil-ity** *n.* — **in-e-dif-fi-ably** *adv.*

in-e-dif-fec-tive (in-êd'fêk'tiv) *adj.* 1. Not causing an intended effect <an ineffective petition>. 2. Incapable of performing efficiently <an ineffective executive officer>. — **in-e-dif-fec-tive-ly** *adv.* — **in-e-dif-fec-tive-ness** *n.*

in-e-dif-fec-tual (in-êd'fêk'chô-ol) *adj.* 1. INEFFECTIVE. 2. Lacking the ability to do or perform effectively: POWERLESS. — **in-e-dif-fec-tual-ity**, **in-e-dif-fec-tual-ness** *n.* — **in-e-dif-fec-tual-ly** *adv.*

in-e-dif-fi-ca-cious (in-êd'fî-kâ'shâs) *adj.* INEFFECTIVE. 1. — **in-e-dif-fi-ca-cious-ly** *adv.* — **in-e-dif-fi-ca-cious-ness** *n.* — **in-e-dif-fi-ca-cy** (-kâ-sê) *n.*

in-e-dif-fi-cient (in-êd'fîsh'ân-sê) *n.*, pl. -**cies**. 1. The quality, state, or fact of being inefficient. 2. Something inefficient.

in-e-dif-fi-cient (in-êd'fîsh'ant) *adj.* 1. Not efficient. 2. Lacking in ability: INCOMPETENT. 3. Wasteful of time, energy, or materials. 4. Not causing the intended result. — **in-e-dif-fi-cient-ly** *adv.*

in-e-las-tic (in-ê-lâs'tik) *adj.* 1. Not elastic: UNYIELDING. 2. Not responding or adapting readily to change. — **in-e-las-tic-ity** (-lâs-tis'tê-tê) *n.*

in-e-le-gant (in-êl'î-gant) *adj.* [OFr. < Lat. *inelegans*: in-, not & *elegans*, elegant.] 1. Lacking elegance. 2. Without refinement or polish. — **in-e-le-gant-ly** *adv.* — **in-e-le-gance** *n.*

in-e-li-gi-ble (in-êl'î-jâ-bul) *adj.* 1. Not qualified for election or appointment to an office or position. 2. Not worthy of being chosen. — **in-e-li-gi-bil-ity** *n.* — **in-e-li-gi-bly** *adv.*

in-e-lo-quent (in-êl'ô-kwânt) *adj.* Not eloquent. — **in-e'lô-quence** *n.* — **in-e'lô-o-quent-ly** *adv.*

in-e-luc-ta-ble (in-êl'ûk'tâ-bul) *adj.* [Lat. *ineluctabilis*: in-, not & *eluctari*, to struggle out of (ex-, out & *luctari*, to struggle).] 1. Not to be avoided or overcome: INESCAPABLE <ineluctable consequences>.

— **in-e-luc-ta-bil-ity** *n.* — **in-e-luc-ta-bly** *adv.*

in-ept (in-êpt') *adj.* [Lat. *ineptus*: in-, not & *aptus*, suitable. — *see* **APT**.] 1. Not suitable to the situation or occasion: INAPPROPRIATE. 2. Lacking in judgment, sense, or reason: FOOLISH. 3. Incompetent. — **in-ept-ly** *adv.* — **in-ept-ness** *n.* — **in-ept-ly** *adv.*

in-equal-ity (in-êkwôl'ê-tê) *n.*, pl. -**ties**. 1. An instance or the state of being unequal. 2. Social or economic disparity. 3. Lack of regularity: UNEVENNESS. 4. Variability: changeability. 5. Math. An algebraic statement that a quantity is greater than or less than another quantity.

* **syns**: INEQUALITY, DISPARITY, DISPROPORTION *n.* core meaning: the condition or fact of being unequal, as in age, rank, or degree <the inequality between the rich and the poor>.

in-equi-ta-ble (in-êkwî-tâ-bul) *adj.* [Lat. *inequitas*: INEQUITY. — *see* **APT**.] 1. Not equitable: UNFAIR. — **in-equi-ta-bly** *adv.*

in-equi-ty (in-êkwî-tê) *n.*, pl. -**ties**. 1. Injustice: unfairness. 2. An instance of injustice or unfairness.

in-e-rad-i-ca-ble (in-êrad'î-kâ-bul) *adj.* Incapable of being eradicated. — **in-e-rad-i-ca-bly** *adv.*

in-er-rant (in-êr-rant) *adj.* Free from errors. — **in-er-ran-cy** *n.*

in-ert (in-êrt') *adj.* [Lat. *iners*, inert, inactive: in-, not & *ars*, skill.] 1. Unable to move or act. 2. Moving or acting very slowly: SLUGGISH. 3. Chem. a. Displaying no chemical activity. b. Displaying chemical activity only under special or extreme conditions. — **in-ert-ly** *adv.* — **in-ert-ness** *n.*

in-er-tia (in-êr'ti-shâ) *n.* [NLat. < Lat., idleness < *iners*, inert.] 1. Physics. The tendency of a body to resist acceleration, as the tendency of a body at rest to remain at rest or of a body in motion to stay in motion in a straight line unless disturbed by an external force. 2. Resistance to change or motion. — **in-er-tial** *adj.* — **in-er-tial-ly** *adv.*

â pat â pay âr care â father ê pet ê be hw hwich i tie îr pier ô pot ô toe ô paw, lor oi noise

Lemieux Exhibit 5

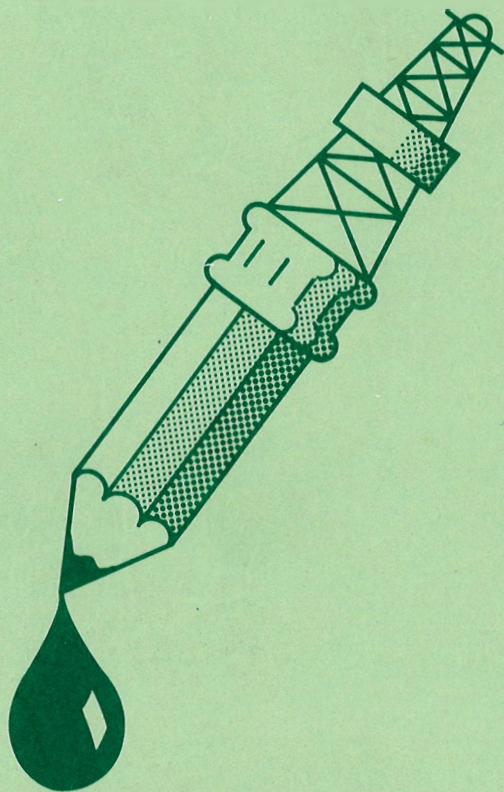
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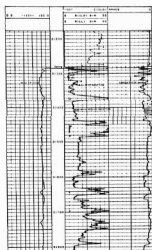
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INDUCTION SURVEY

induction survey *n*: an electric well log in which the conductivity of the formation rather than the resistivity is measured. Because oil-bearing formations are less conductive of electricity than water-bearing formations, an induction survey, when compared with resistivity readings, can aid in determination of oil and water zones.

indurated *adj*: hardened, as in indurated steel.

inelastic collision *n*: the collision of a neutron and the nucleus of an atom in which the total energy of the neutron is absorbed by the nucleus.

inert gas *n*: 1. the part of a breathing medium, such as helium, that serves as a transport for oxygen and is not used by the body as a life-support agent. Its purpose is to dilute the flow of oxygen to the lungs, thereby preventing oxygen toxicity. 2. in chemistry, gases that have a filled outer electron shell and thus do not easily react with other substances. Examples are helium, argon, neon, and xenon.

inertia *n*: the tendency of an object having mass to resist a change in velocity.

inertia brake *n*: a brake that utilizes the energy of a heavy, turning member to actuate the braking action.

inerting *n*: 1. the process of pressurizing the vapor space of a vessel with an inert gas blanket (usually exhaust gas) to prevent the formation of an explosive mixture. 2. a procedure used to reduce the oxygen content of a vessel's cargo spaces to 8 percent or less by volume by introducing an inert gas such as nitrogen or carbon dioxide or a mixture of gases such as flue gas.

inferential mass meter *n*: a volume meter with the addition of a densitometer from which mass flow is inferred.

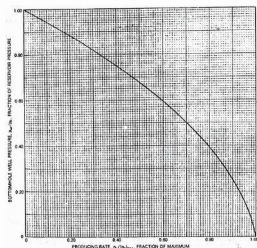
infill drilling *n*: drilling wells between known producing wells to exploit the resources of a field to best advantage.

infilling well *n*: a well drilled between known producing wells to exploit the reservoir better.

inflow performance relationship (IPR) *n*: the relation between the midpoint pressure of the producing reservoir and the liquid inflow rate of a producing well.

inflow performance relationship curve *n*: a productivity curve plotted when a well has two-phase flow, both oil and gas, based on well tests or a combination of computations and well tests. Also called IPR curve.

INFLOW PERFORMANCE RELATIONSHIP CURVE



influx *n*: an intrusion of formation fluids into the borehole, i.e., a kick.

INGAA *abbr*: Interstate Natural Gas Association of America.

inherent motor temperature protection *n*: overload or short-circuit protection built into the motor windings.

inhibited acid *n*: an acid that has been chemically treated before the acidizing or acid fracturing of a well to lessen its corrosive effect on the tubular goods and yet maintain its effectiveness. See *acid fracturing*, *acidize*.

inhibited mud *n*: a drilling fluid to which chemicals have been added to prevent it from causing clay particles in a formation to swell and thus impair the permeability of a productive zone. Salt is a mud inhibitor.

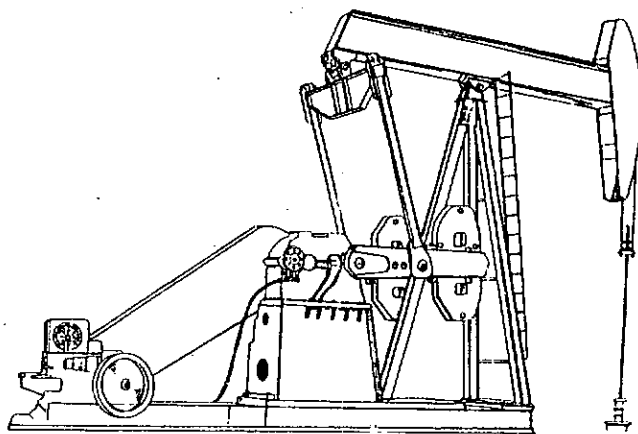
inhibitor *n*: an additive used to retard undesirable chemical action in a product. It is added in small quantities to gasolines to prevent oxidation and gum formation, to lubricating oils to stop color change, and to corrosive environments to decrease corrosive action.

initial circulating pressure (ICP) *n*: the pressure at which a well that has been closed in on a kick is circulated when well-killing procedures are begun.

Lemieux Exhibit 6

Dictionary of Petroleum Exploration, Drilling, & Production

Norman J. Hyne, Ph.D.



PennWell Books

PENNWELL PUBLISHING COMPANY
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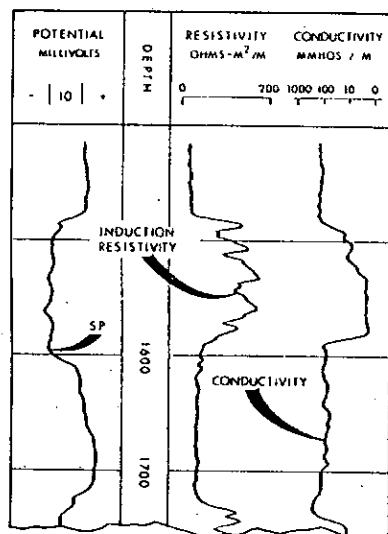
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induction 1) electromagnetic induction, is the generation of an electric current in a conductor exposed to a changing magnetic field or a conductor moving through a magnetic field 2) magnetic induction is the magnetic flux density or magnetic field and is also the process of magnetizing a substance by applying a magnetic field. *ind or ind*

Induction-Electrolog™ a combination induction and short normal or laterolog



induction log

induction log or induction-electric log a type of electric log that was developed in the mid-1970s for wells drilled with nonconductive fluids such as oil-base mud. The induction tool forms electrical currents called ground loops in the formations adjacent to the wellbore. The log is recorded as either conductivity and/or its inverse, resistivity. The induction electric log has a depth of investigation of 5–20 ft and a resolution of 3–5 ft. The induction log is used today in wells drilled with fresh water-base and oil-base muds and air to determine R_t and R_i along with spontaneous potential (SP). A dual induction laterolog has a deep investigation (IL_d) and a medium induction curve (IL_m) curve. *IEL, IL, or I*

induction tool or sonde a well-logging tool that creates circular electrical currents that are vertically concentric and extend out into the formation adjacent to the wellbore. The induction tool uses a conductor coil to create a high-frequency magnetic field when a 20-kHz electric current is passed through it. The magnetic field causes electric currents called ground loops to form in the surrounding formation. The strength of the ground loops are proportional to the conductivity of the formation. The ground loops set up a secondary magnetic field that is measured on a receiver coil in the tool. Induction tools can be focused to minimize borehole and invaded zone effects. The number of transmitter and receiver coils and their spacing determines the depth of investigation, borehole response, and bed resolution.

inductor a coil of wire, usually wrapped around an iron core, that can store energy in the form of a magnetic field. When an electric current is passed through the wire, a magnetic field forms. When the

electric current is stopped, the magnetic field collapses, causing a brief electric current to flow in the opposite direction of the original current. Inductance is the strength of the magnetic field generated by a current flowing through the wire and is measured in henrys.

indur indurated

indurated a rock made hard by heat, pressure, and natural cementation. *indur or ind*

inelastic collision a collision in which the kinetic energy of the colliding particles is not the same before as after the collision, in contrast to an elastic collision

inelastic scattering a type of scattering in which a neutron strikes the nucleus of an atom and imparts more kinetic energy to the nucleus than would be expected in a simple elastic collision. The nucleus is transformed into an excited state and returns to ground state by emitting one or more gamma rays. The scattered neutron bounces off the nucleus with significantly less energy. Inelastic scattering is in contrast to elastic scattering.

inert fraction the part of the drilling mud, such as well cuttings and weighing materials, that does not add to the mud gel strength. The inert fraction is in contrast to the colloidal fraction.

inert gas a gas that will not chemically react with other substances. Helium, neon, argon, krypton, xenon, and radon are inert gases.

inert gas injection an enhanced oil-recovery technique in which an inert gas such as carbon dioxide or nitrogen is injected into a depleted oil well. Lighter hydrocarbons from the oil migrate to the carbon dioxide to form a miscible front which is soluble with the oil. This reduces the capillary pressure of the oil that holds the oil in the pores and makes it more fluid. Nitrogen is not miscible with oil. The inert gas pushes the oil toward producing wells.

inertia brake a device that slows rotation by using a heavy, rotating mass

inertial navigation navigation that uses an inertial platform with two pendulums at right angles. The platform is held level by three fast-opening gyroscopes at right angles.

inertinite a kerogen maceral that is composed of reworked organic matter. Inertinite is highly oxidized, inert, and has very little potential to generate petroleum.

inert solids particles in drilling mud that are chemically inactive. The inerts include well cuttings, weighting, and lost circulation materials. Inert solids are in contrast to the reactive fraction that includes the clay minerals, such as bentonite and attapulgite.

infauna animals living in the sediments

inferential meter a meter that infers gas volume by measuring differential pressure and flow rate. Orifice, turbine, and mass flowmeters are inferential meters in contrast to positive displacement meters.

INF-G inflammable gas

in fill, infill, or infilling well a well drilled between producing wells to increase production and possibly ultimate recovery from the reservoir. An in fill well is not necessary to hold the lease. *AW*

Lemieux Transcript

<p>1 IN THE CIRCUIT UNITED STATES DISTRICT COURT, DISTRICT OF DELAWARE.</p> <p>2</p> <p>3</p> <p>4</p> <p>5 GENERAL ELECTRIC COMPANY,</p> <p>6</p> <p>7 Plaintiff,</p> <p>8</p> <p>9 VS.</p> <p>10</p> <p>11 LPP COMBUSTION, LLC</p> <p>12</p> <p>13 Defendant,</p> <p>14</p> <p>15 Case No. 1:22-cv-00720-GBW</p> <p>16</p> <p>17</p> <p>18 DEPOSITION OF PATRICK LEMIEUX</p> <p>19</p> <p>20 TAKEN ON BEHALF OF THE DEFENDANT</p> <p>21</p> <p>22 May 30th, 2023</p> <p>23</p> <p>24 (Starting time of the deposition: 3:00 p.m.)</p> <p>25</p>	<p>Page 1</p>	<p>1 IN THE UNITED STATES DISTRICT COURT, DISTRICT OF DELAWARE.</p> <p>2</p> <p>3 GENERAL ELECTRIC COMPANY,)</p> <p>4) PLAINTIFF,)</p> <p>5) vs.) Case No. Case No. 1:22-cv-00720-GBW</p> <p>6) LPP COMBUSTION, LLC,)</p> <p>7) DEFENDANT.)</p> <p>8</p> <p>9</p> <p>10</p> <p>11</p> <p>12</p> <p>13 DEPOSITION OF PATRICK LEMIEUX produced, sworn and</p> <p>14 examined on May 30th, 2023, between the hours of nine o'clock in</p> <p>15 the forenoon and six o'clock in the evening of that day, via</p> <p>16 ZOOM before Paula D. Hefner, a Certified Shorthand Reporter,</p> <p>17 Certified Court Reporter, Registered Merit Reporter, Certified</p> <p>18 Real-Time Reporter, and a Notary Public within and for the State</p> <p>19 of Missouri, in a certain cause now pending in the United States</p> <p>20 District Court, District of Delaware, wherein GENERAL ELECTRIC</p> <p>21 COMPANY is the PLAINTIFF, and LPP COMBUSTION, LLC is the</p> <p>22 DEFENDANT, on behalf of the DEFENDANT.</p> <p>23</p> <p>24</p> <p>25</p>	<p>Page 3</p>
<p>1 INDEX</p> <p>2 QUESTIONS BY: PAGE</p> <p>3 MR. HART..... 5</p> <p>4</p> <p>5</p> <p>6</p> <p>7</p> <p>8</p> <p>9 EXHIBITS</p> <p>10</p> <p>11 No exhibits marked.</p> <p>12</p> <p>13</p> <p>14</p> <p>15</p> <p>16</p> <p>17</p> <p>18</p> <p>19</p> <p>20</p> <p>21</p> <p>22</p> <p>23</p> <p>24</p> <p>25</p>	<p>Page 2</p>	<p>1 A P P E A R A N C E S</p> <p>2 FOR THE PLAINTIFF:</p> <p>3 TIMOTHY P. BEST, ESQ. (VIA ZOOM)</p> <p>4 PHILIP J. SPEAR, ESQ.</p> <p>5 GIBSON, DUNN & CRUTCHER, LLP</p> <p>6 333 South Grand Avenue</p> <p>7 Los Angeles, California 90071</p> <p>8 (213) 229-7659</p> <p>9 tbest@gibsondunn.com</p> <p>10 pspear@gibsondunn.com</p> <p>11</p> <p>12 ANTHONY WALSH, ESQ. (VIA ZOOM)</p> <p>13 In-House Counsel</p> <p>14 General Electric Company</p> <p>15 4200 Wildwood Parkway</p> <p>16 Atlanta, Georgia 30339</p> <p>17 (404) 386-4559</p> <p>18 anthony.walsh@ge.com</p> <p>19</p> <p>20 JURGEN HOFFMAN, ESQ. (VIA ZOOM)</p> <p>21 THEODOROS STAMATIADIS, ESQ. (VIA ZOOM)</p> <p>22 In-House Counsel</p> <p>23 General Electric Company</p> <p>24 5400 Baden</p> <p>25 Switzerland</p> <p>26 +41 79 619 2274</p> <p>27 jun.hoffman@ge.com</p> <p>28 theodoros.stamatiadis@ge.com</p> <p>29</p> <p>30 FOR THE DEFENDANT:</p> <p>31 PAUL HART, ESQ. (VIA ZOOM)</p> <p>32 ERISE IP PA</p> <p>33 5299 DTC Boulevard, Suite 1340</p> <p>34 Greenwood Village, Colorado 80111</p> <p>35 (913-777-5600</p> <p>36 paul.hart@eriseip.com</p> <p>37</p> <p>38 Court Reporter:</p> <p>39 Paula D. Hefner, CSR, CCR, RMR, CRR</p> <p>40 Missouri CCR #219</p> <p>41 Lexitas Litigation Services</p> <p>42 711 North Eleventh Street</p> <p>43 St. Louis, Missouri 63101</p> <p>44 (314) 644-2191 telephone</p> <p>45 1-800-280-3376 toll free</p>	<p>Page 4</p>

<p style="text-align: right;">Page 5</p> <p style="text-align: center;">ROUGH-DRAFT TRANSCRIPT OF PATRICK LEMIEUX</p> <p>1 IT IS HEREBY STIPULATED AND AGREED by and between</p> <p>2 counsel for the Plaintiff and counsel for the Defendant that</p> <p>3 this deposition may be taken in shorthand by PAULA D. HEFNER, a</p> <p>4 Certified Shorthand Reporter, Certified Court Reporter,</p> <p>5 Registered Merit Reporter, Certified Real-Time Reporter, and a</p> <p>6 Notary Public, and afterwards transcribed into typewriting; and</p> <p>7 the signature of the witness is expressly reserved.</p> <p>8</p> <p>9 * * * * *</p> <p>10</p> <p>11 (Starting time of the deposition: 3:00 p.m.)</p> <p>12</p> <p>13 COURT REPORTER: Would you raise your</p> <p>14 right hand, please?</p> <p>15 Do you swear that the testimony you give will be the</p> <p>16 truth, the whole truth, and nothing but the truth so help you</p> <p>17 God?</p> <p>18 THE WITNESS: Yes.</p> <p>19 COURT REPORTER: Thank you.</p> <p>20</p> <p>21 EXAMINATION</p> <p>22 QUESTIONS BY MR. HART:</p> <p>23 Q. All right. Good afternoon, Dr. Lemieux.</p> <p>24 Before we get going, have you been deposed before?</p> <p>25 A. Yes. I have been deposed once about 2008, 2009 time</p>	<p style="text-align: right;">Page 7</p> <p>1 Mr. Hart, whatever you prefer. Paul is just fine.</p> <p>2 A. Okay.</p> <p>3 Q. All right. Do you have a copy of the declaration that</p> <p>4 you submitted in this proceeding?</p> <p>5 A. I do have a copy.</p> <p>6 Q. Okay.</p> <p>7 A. I have a printed copy and I have an electronic one as</p> <p>8 well.</p> <p>9 Q. Okay. Ryan is online as an exhibit tech so he can</p> <p>10 screen share any documents that we need him to. But, we</p> <p>11 typically find it easier for witnesses to use their own copies</p> <p>12 just so they can control it scrolling up and down as they see</p> <p>13 fit.</p> <p>14 So I will assume as I'm asking you questions about</p> <p>15 your declaration that you'll just be referencing your local copy</p> <p>16 there. But, you know, if we need to screen share for any reason</p> <p>17 Ryan can do it. So just let me know if that would be helpful.</p> <p>18 A. Okay.</p> <p>19 Q. All right. Very good. I would like to start by</p> <p>20 pinning down some basics about the types of combustion systems</p> <p>21 relevant to the '396 Patent in this proceeding that you've</p> <p>22 opined on.</p> <p>23 Can I have you turn to your declaration at Paragraph</p> <p>24 29?</p> <p>25 A. Okay. I'm there.</p>
<p style="text-align: right;">Page 6</p> <p>1 frame.</p> <p>2 Q. All right. Very good. Well, let me go over just some</p> <p>3 basic ground rules just so we're both operating under the same</p> <p>4 assumptions here.</p> <p>5 So it's my job today to ask clear questions. If you</p> <p>6 don't understand any part of a question I ask, please let me</p> <p>7 know.</p> <p>8 The other kind of big point is the Court reporter can</p> <p>9 only take down one of us at a time. So I will do my best not to</p> <p>10 speak over you, and I would just ask that you try not to speak</p> <p>11 over me.</p> <p>12 Your attorney may object from time to time, so also</p> <p>13 keep in mind that we both need to give him room to enter his</p> <p>14 objections into the record.</p> <p>15 One just logistical point: If I do interrupt one of</p> <p>16 your answers before you've completed it, please let me know so I</p> <p>17 can let you finish.</p> <p>18 Is all that understandable?</p> <p>19 Do you have any questions about how this will proceed?</p> <p>20 A. Yeah. This is all clear.</p> <p>21 But, I see on your screen it says Erise IP. Is your</p> <p>22 name Erise or how do I address you?</p> <p>23 Q. No. Sorry. I'm on my conference room system. That's</p> <p>24 the name of my law firm, Erise IP.</p> <p>25 My name is Paul Hart. You can refer to me as Paul or</p>	<p style="text-align: right;">Page 8</p> <p>1 Q. All right. Very good. In Paragraph 29 you note</p> <p>2 generally speaking, combustion processes can be described as</p> <p>3 either diffusion flame combustion systems or lean, premixed</p> <p>4 combustion systems.</p> <p>5 Do you see that?</p> <p>6 A. I do, yes.</p> <p>7 Q. You note that in diffusion flame combustion systems</p> <p>8 fuel and oxidizer are added to the combustion zone in an unmixed</p> <p>9 state. And then you note that mixing of the fuel and air in</p> <p>10 combustion take place simultaneously.</p> <p>11 Is that, is that generally the characteristics of a</p> <p>12 diffusion flame combustion system that the fuel and the air are</p> <p>13 directly added to a combustion zone without a premixing phase?</p> <p>14 A. Yes. That is fundamentally the definition of a</p> <p>15 diffusion system, uh-huh.</p> <p>16 Q. Okay. Turning to Paragraph 30 you continue.</p> <p>17 So-called premix combustion systems, as their name implies,</p> <p>18 thoroughly premix the fuel with air before the mixture enters</p> <p>19 the combustor.</p> <p>20 Do you see that?</p> <p>21 A. I do, uh-huh.</p> <p>22 Q. Okay. Now, in a premixed combustor will there be some</p> <p>23 transit time required for the fuel and the air to reach the</p> <p>24 combustion zone?</p> <p>25 MR. BEST: Objection to form.</p>

<p>Page 9</p> <p>1 A. Yes. It really depends on the geometry of the system.</p> <p>2 But, typically by and large there is, yeah. The pre-mixer is</p> <p>3 separated from the combustor zone and so, therefore, there is a</p> <p>4 transit time for the mixture to reach the point at which one</p> <p>5 desires it to combust. In general.</p> <p>6 Q. (By Mr. Hart) Okay. Very good. If we use the</p> <p>7 example of a natural gas combustion device that is a premix</p> <p>8 natural gas combustion system. That natural gas premixed</p> <p>9 combustion device is designed such that the mixture of natural</p> <p>10 gas and air withstands combustion -- or fails to combust -- over</p> <p>11 that transit time until the mixture reaches the combustion zone</p> <p>12 and the flame front. Correct?</p> <p>13 MR. BEST: Objection to form; including beyond</p> <p>14 the scope.</p> <p>15 A. I'm sorry, could you repeat the question? I'm not</p> <p>16 sure I gathered it.</p> <p>17 Are you saying that there is a pre-mixer where the</p> <p>18 proportion of fuel and proportion of oxidizer is such that there</p> <p>19 is no combustion? Is that what you're saying?</p> <p>20 Q. (By Mr. Hart) I guess I'm trying to get at kind of a</p> <p>21 layout, a sequence of events.</p> <p>22 We have a pre-mixer, we have some transit path that</p> <p>23 has an associated transit time, and then we have a combustion</p> <p>24 zone.</p> <p>25 Is that right?</p>	<p>Page 11</p> <p>1 the scope.</p> <p>2 A. It's not, you know -- I didn't do a survey of it. I</p> <p>3 can't think of a model right now that would satisfy the set-up</p> <p>4 that you're describing.</p> <p>5 But, that doesn't mean that there isn't.</p> <p>6 Q. (By Mr. Hart) Okay. That description of a premix</p> <p>7 zone followed by a transit path before you get to the combustion</p> <p>8 zone, that is a reasonable description of a common form of</p> <p>9 premix combustion system.</p> <p>10 Is that fair?</p> <p>11 MR. BEST: Same objections.</p> <p>12 A. It's a type that satisfies the basic premise or set-up</p> <p>13 of a premix combustor, you know, which is that it involves a</p> <p>14 premixing zone before it enters a combustor -- combustion area.</p> <p>15 Q. (By Mr. Hart) Okay. For today's conversation can we</p> <p>16 refer to the time between the point at which fuel, gas, and air</p> <p>17 are introduced and the time in which that mixture reaches the</p> <p>18 combustion zone as a transit time?</p> <p>19 MR. BEST: Objection to form.</p> <p>20 A. Yeah. If we're describing, you know, a specific type</p> <p>21 of premix combustor, where you know, there is a -- you know,</p> <p>22 such a set-up where there is quantifiable time between the</p> <p>23 pre-mixer and the combustion zone sure. That would be one of</p> <p>24 those set-ups.</p> <p>25 Q. (By Mr. Hart) All right. Very good. Can you scroll</p>
<p>Page 10</p> <p>1 MR. BEST: Objection to form; including lack of</p> <p>2 foundation; beyond the scope.</p> <p>3 A. Yeah. I mean I think you're describing, you know, a</p> <p>4 very specific kind of a set-up. The way you're describing it is</p> <p>5 not inconsistent with what a pre-mixed combustor might look</p> <p>6 like. But, it's by no means necessarily the only way that a</p> <p>7 pre-mixer could work.</p> <p>8 I mean maybe if you showed me an example of what</p> <p>9 you're describing here that would help.</p> <p>10 Q. (By Mr. Hart) Okay. I think, you know -- I think</p> <p>11 we've got the general point down that there is some kind of</p> <p>12 transit path and a transit time associated with these premixed</p> <p>13 combustion systems.</p> <p>14 It is fair to say that after the oxygen or the air and</p> <p>15 the fuel gas are introduced to one another there is some transit</p> <p>16 time that occurs before they reach the combustion zone.</p> <p>17 Correct?</p> <p>18 MR. BEST: Same objections.</p> <p>19 A. Again, this is going to be case specific. It's going</p> <p>20 to depend on the geometry and the engineering of the combustor</p> <p>21 and the pre-mixer set-up.</p> <p>22 Q. (By Mr. Hart) Are you aware of any premix natural gas</p> <p>23 combustion systems that do not involve some kind of transit path</p> <p>24 between the premix zone and the combustion zone?</p> <p>25 MR. BEST: Objection to form; including beyond</p>	<p>Page 12</p> <p>1 down to Paragraph 31 in your declaration for me, please?</p> <p>2 A. I can. Okay. I'm there.</p> <p>3 Q. Very good. So right in the middle of that paragraph</p> <p>4 you are quoting the '396 Patent in Column 1 Lines 56 to 67.</p> <p>5 Do you see that quote?</p> <p>6 A. Give me a moment there to get there.</p> <p>7 Q. Sure.</p> <p>8 A. Describing the auto-ignition phenomena.</p> <p>9 Q. Exactly. Right. So you know that the '396 Patent</p> <p>10 describes an issue it refers to as auto-ignition in which</p> <p>11 combustion occurs upstream of the intended combustion zone.</p> <p>12 Is that right?</p> <p>13 A. Yes. I'm aware that Patent '396 refers to that</p> <p>14 specifically, uh-huh.</p> <p>15 Q. Okay. And so the problem targeted by the '396 Patent</p> <p>16 occurs when a fuel and air mixture combust before it reaches</p> <p>17 that target combustion zone. Correct?</p> <p>18 MR. BEST: Objection to form; including calling</p> <p>19 for a legal conclusion.</p> <p>20 A. I mean I saw extensive references to other ignition in</p> <p>21 the '396 Patent and, you know, that it aims at preventing that</p> <p>22 problem.</p> <p>23 Q. (By Mr. Hart) Okay. And I'm just trying to probe</p> <p>24 your understanding of what that problem is in the '396 Patent,</p> <p>25 you know.</p>

<p style="text-align: right;">Page 13</p> <p>1 You've opined extensively about the '396 Patent and</p> <p>2 about how the terms and the claims of the '396 Patent should be</p> <p>3 interpreted by the Court.</p> <p>4 Is it correct that in the context of this</p> <p>5 auto-ignition problem being discussed by the '396 Patent there</p> <p>6 is some amount of time that it takes for a fuel and air mixture</p> <p>7 to combust?</p> <p>8 MR. BEST: Objection to form; including lack of</p> <p>9 foundation in multiple respects.</p> <p>10 A. Well, would it be a -- would it be reasonable to look</p> <p>11 at exactly the parts of the patent that you are referring to</p> <p>12 that would make that clear?</p> <p>13 Q. (By Mr. Hart) Yeah. You can certainly point me to</p> <p>14 any part of the patent.</p> <p>15 What might be easier is can you describe for me what</p> <p>16 the problematic auto-ignition problem is that the '396 Patent</p> <p>17 identifies and that you've discussed in your declaration?</p> <p>18 MR. BEST: Again, same objections.</p> <p>19 A. Do I need to describe it to you or are you describing</p> <p>20 it to me and seeing if I agree with it? I mean I know --</p> <p>21 Q. (By Mr. Hart) No, I mean -- I'm sorry, go ahead.</p> <p>22 Finish your answer.</p> <p>23 A. I know that auto-ignition can be a problem, and I know</p> <p>24 that '396 attempts to provide a solution to solving that</p> <p>25 problem, you know, and offers a system that appears to solve</p>	<p style="text-align: right;">Page 15</p> <p>1 MR. BEST: Pardon. Objection; form, including</p> <p>2 vague, including beyond the scope.</p> <p>3 Go ahead.</p> <p>4 A. Yeah. I'm familiar with chemical kinetics.</p> <p>5 But, this is not -- nothing that I've opined on in any</p> <p>6 declaration or really, you know, prepared for for today for</p> <p>7 sure.</p> <p>8 Q. (By Mr. Hart) What Is chemical kinetics?</p> <p>9 MR. BEST: Same objections.</p> <p>10 A. Yeah. I'm not really prepared to define it right now.</p> <p>11 It's a technical term that, you know, discussed the</p> <p>12 phenomenon upon which combustion is premised, you know.</p> <p>13 But, if -- I would need to research it to give you an</p> <p>14 on the record precise definition more thoroughly.</p> <p>15 Q. (By Mr. Hart) Have you considered the timing aspects</p> <p>16 of combustion at all in preparing your declaration for this</p> <p>17 case?</p> <p>18 MR. BEST: Objection; form; including lack of</p> <p>19 foundation; including vague.</p> <p>20 A. I'm not sure what you mean by timing in this context.</p> <p>21 Are you talking like in the context of the claims of</p> <p>22 '396, or specifically what are you referring to when you are</p> <p>23 saying timing?</p> <p>24 Q. (By Mr. Hart) Sure. So just to add some context</p> <p>25 here. The '396 Patent is describing a phenomenon known as</p>
<p style="text-align: right;">Page 14</p> <p>1 that problem. You know, that -- I can agree with all that.</p> <p>2 But, I mean I'm not exactly sure what you're asking</p> <p>3 me.</p> <p>4 Q. All right. How about this. If we assume that there</p> <p>5 is a premix zone separated by some transit path that connects it</p> <p>6 to the combustion zone is it true that a problem described by</p> <p>7 the '396 Patent is when the fuel and air are introduced together</p> <p>8 in the premix zone that sometimes they may combust before they</p> <p>9 reach the combustion zone?</p> <p>10 MR. BEST: Well, objection to form; lack of</p> <p>11 foundation in multiple respects; it seems like it's beyond the</p> <p>12 scope.</p> <p>13 A. I think, yeah -- I think this is not really something</p> <p>14 that I've opined on in my declaration, you know, a description</p> <p>15 of the system the way you're presenting it.</p> <p>16 I mean if you feel that that's how -- specifically how</p> <p>17 the '396 Patent looks at the set-up, you know, I'm happy to look</p> <p>18 at it again.</p> <p>19 I really did not spend much time establishing the</p> <p>20 geometry of the combustor. I think this is what you're focusing</p> <p>21 on, the geometry of the set-up.</p> <p>22 Q. (By Mr. Hart) Yeah. So, I believe it's been referred</p> <p>23 to as chemistry kinetics. Are you familiar with the phrase</p> <p>24 chemistry kinetics?</p> <p>25 A. Yeah. We call it --</p>	<p style="text-align: right;">Page 16</p> <p>1 auto-ignition or premature combustion where the auto-ignition</p> <p>2 time for certain fuels introduced to a system is shorter than</p> <p>3 the transit time for that fuel mixture to reach the combustion</p> <p>4 zone and that's why it combusts before the intended combustion</p> <p>5 zone.</p> <p>6 Have you considered those timing relationships in any</p> <p>7 form or fashion in preparing your declaration?</p> <p>8 MR. BEST: Well, objection to form; compound as</p> <p>9 well as lack of foundation in multiple respects.</p> <p>10 A. Well, I've considered timing in the sense that, you</p> <p>11 know, I know what auto-ignition is and, you know, it can be</p> <p>12 interpreted to refer to, you know -- to a mismatch in when</p> <p>13 ignition occurs or the beginning of combustion occurs compared</p> <p>14 to when it should by design in the combustor -- in the combustor</p> <p>15 process itself. So I did consider this. Absolutely.</p> <p>16 Q. (By Mr. Hart) What terms would you like to use to</p> <p>17 describe those two times that you just noted in your answer?</p> <p>18 The time when auto-ignition actually occurs and the</p> <p>19 time when auto -- when ignition or when combustion is intended</p> <p>20 to occur?</p> <p>21 MR. BEST: Objection to form.</p> <p>22 A. I don't have a preferred terminology for those times.</p> <p>23 Whatever you want to call it that's fine with me.</p> <p>24 I think we understand that there's, you know, a</p> <p>25 difference between, you know -- the targeted time to ignition</p>

<p style="text-align: right;">Page 17</p> <p>1 and the actual time of ignition I think is what you're referring</p> <p>2 to here and, yeah. That's what auto-ignition -- you know,</p> <p>3 premature auto-ignition would be.</p> <p>4 Q. (By Mr. Hart) Okay. If we refer to the time that</p> <p>5 combustion actually occurs as the auto-ignition time and the</p> <p>6 time that was intended for combustion as the transit time do you</p> <p>7 understand what I mean when I use those phrases?</p> <p>8 MR. BEST: Objection to form; beyond the scope;</p> <p>9 lack of foundation; among other things.</p> <p>10 A. I mean I understand what you are saying. But, I wish</p> <p>11 you would bring it back to sort of my declaration specifically</p> <p>12 to where that's, you know -- that's relevant to what I've said.</p> <p>13 Q. (By Mr. Hart) Okay. But, you do understand what I</p> <p>14 mean when I use those phrases in this context?</p> <p>15 MR. BEST: Same objections.</p> <p>16 A. Yes. I understand what you are saying.</p> <p>17 Q. (By Mr. Hart) Okay. Very good.</p> <p>18 Would you agree that a problem the '396 discusses and</p> <p>19 that you address in your declaration is the situation in which</p> <p>20 the auto-ignition time is shorter than the transit time in a</p> <p>21 premixed combustion device?</p> <p>22 MR. BEST: Objection; form; lack of foundation.</p> <p>23 A. Yeah. I mean in the context of the claims of the '396</p> <p>24 Patent I think that that's, you know, a general representation</p> <p>25 of what it is trying to address.</p>	<p style="text-align: right;">Page 19</p> <p>1 Q. So for any fuel, air mix you can have too little or</p> <p>2 too much fuel to support combustion.</p> <p>3 Is that right?</p> <p>4 MR. BEST: Objection; form.</p> <p>5 A. Yes. That is correct. In fact, that's bound by these</p> <p>6 two limits that we've just described.</p> <p>7 Q. (By Mr. Hart) Okay. Can I have you scroll down to</p> <p>8 your declaration of Paragraph 43, please?</p> <p>9 A. Okay. I'm there.</p> <p>10 Q. All right. So the very last sentence in Paragraph 43</p> <p>11 state: As I discuss below, whether a fuel reacts or combusts is</p> <p>12 related to the concentration of the fuel and the concentration</p> <p>13 of an oxidizer such as air present in the mixture. It is this</p> <p>14 tendency to react with air (i.e., combust) that has the</p> <p>15 potential to lead to auto-ignition upstream of the combustion</p> <p>16 zone.</p> <p>17 Do you see that?</p> <p>18 A. Yes. I see that, uh-huh.</p> <p>19 Q. All right. I think based on the discussion of</p> <p>20 flammability we just referred to any mixture of fuel and air</p> <p>21 must be between the lower and upper flammability limits to</p> <p>22 support auto-ignition upstream of the combustion zone. Correct?</p> <p>23 MR. BEST: Objection to form for including</p> <p>24 incomplete hypothetical.</p> <p>25 A. By definition that would be true.</p>
<p style="text-align: right;">Page 18</p> <p>1 Q. (By Mr. Hart) Very good. Let's turn to Paragraph 32</p> <p>2 of your declaration that starts on Page 12.</p> <p>3 Let me know when you're there.</p> <p>4 A. Okay. I'm there.</p> <p>5 Q. All right. Very good. You discuss a concept you</p> <p>6 refer to as flammability, and you refer to a lower flammability</p> <p>7 limit and an upper flammability limit.</p> <p>8 Do you see that?</p> <p>9 A. I do.</p> <p>10 Q. Am I correct that the lower flammability limit defines</p> <p>11 the minimum amount of air that must be included in a fuel mix to</p> <p>12 support combustion?</p> <p>13 MR. BEST: Objection --</p> <p>14 A. No.</p> <p>15 MR. BEST: Go ahead.</p> <p>16 A. No. You would be incorrect.</p> <p>17 Q. (By Mr. Hart) Okay. What is the upper</p> <p>18 flammability -- I'm sorry.</p> <p>19 What is the lower flammability limit?</p> <p>20 A. It's the minimum amount of fuel, not air, that must be</p> <p>21 present by volume in an air -- fuel to air mixture.</p> <p>22 Q. And what is the upper flammability limit?</p> <p>23 A. It would be the converse. It would be the maximum</p> <p>24 amount of fuel mixed in with air at which combustion can be</p> <p>25 sustained on a per fuel basis.</p>	<p style="text-align: right;">Page 20</p> <p>1 Q. (By Mr. Hart) What other factors influence whether a</p> <p>2 fuel and air mixture will spontaneously combust upstream of the</p> <p>3 combustion zone?</p> <p>4 MR. BEST: Objection to form; incomplete</p> <p>5 hypothetical.</p> <p>6 A. There are many factors. This is a minimum</p> <p>7 requirement, if you will.</p> <p>8 If the fuel is outside those two limits -- lower</p> <p>9 flammability limits and upper flammability limit, LFL, UFL --</p> <p>10 then we're done. Nothing will happen for sure.</p> <p>11 However, if you are within that zone, you know, there</p> <p>12 is a variety of factors that are going to affect exactly when</p> <p>13 this auto-ignition will occur, you know. There is more than one</p> <p>14 factor is what I'm getting at.</p> <p>15 Q. (By Mr. Hart) Can you name any other factors?</p> <p>16 MR. BEST: Same objection.</p> <p>17 A. Well, one, for instance, would be temperature. Flow</p> <p>18 temperature. If the flow temperature is high enough -- and</p> <p>19 you're within the LFL and UEL (sic) then auto-ignition can occur</p> <p>20 at that point.</p> <p>21 Q. (By Mr. Hart) Does pressure influence whether</p> <p>22 auto-ignition will occur?</p> <p>23 MR. BEST: Same objections.</p> <p>24 A. The influence of pressure on auto-ignition temperature</p> <p>25 is much less than that of temperature in general.</p>

<p style="text-align: right;">Page 21</p> <p>1 Q. (By Mr. Hart) How about the specific fuel such as the</p> <p>2 energy content of the fuel: Does that influence whether</p> <p>3 auto-ignition will occur?</p> <p>4 MR. BEST: Same objections; including beyond the</p> <p>5 scope.</p> <p>6 A. Yeah. It's not something that I've opined on. There</p> <p>7 are many factors, as I said, that affect auto-ignition point.</p> <p>8 And auto-ignition is generally referred to as, you know, the</p> <p>9 temperature which this just happens. So different fuels will</p> <p>10 have that different minimum point at which auto-ignition is</p> <p>11 likely to occur.</p> <p>12 Whether it is directly dependent on the lower heating</p> <p>13 value of the fuel -- which is what you're alluding to here --</p> <p>14 I'm not prepared to, you know, to discuss that or to opine on</p> <p>15 that without doing more research.</p> <p>16 Q. (By Mr. Hart) Could I have you scroll down to your</p> <p>17 declaration at Paragraph 45?</p> <p>18 A. Okay. I'm there.</p> <p>19 Q. All right. Very good.</p> <p>20 About halfway down that Paragraph 45 you discuss</p> <p>21 pentane and methane, and specifically mixing pentane and methane</p> <p>22 in a combustion system.</p> <p>23 Do you see that discussion?</p> <p>24 A. Hold on, please. I'm not -- I'm not seeing it just</p> <p>25 yet.</p>	<p style="text-align: right;">Page 23</p> <p>1 and the methane hydrocarbons here since you've discussed them in</p> <p>2 Paragraph 45.</p> <p>3 In a first example we mix pentane with air in a</p> <p>4 premixed combustion device such that the resulting mixture falls</p> <p>5 within the flammability range. And a second example we mix</p> <p>6 methane with air in a premix combustion device such that the</p> <p>7 resulting mixture also falls within the flammability range.</p> <p>8 If the device is designed such that both examples</p> <p>9 would experience premature auto-ignition before the combustion</p> <p>10 chamber would the pentane mixture experience auto-ignition</p> <p>11 faster or further upstream than the methane mixture?</p> <p>12 MR. BEST: I'm not sure I followed all that.</p> <p>13 Objection to form; compound in multiple respects; lack of</p> <p>14 foundation in multiple respects, amongst other things.</p> <p>15 A. Well, a general rule of thumb: Generally the higher</p> <p>16 order hydrocarbon can experience auto-ignition sooner.</p> <p>17 So given that pentane is C5 and methane is C1, one</p> <p>18 might expect the scenario you've described to apply.</p> <p>19 You know, we would have to do more analysis there to</p> <p>20 really verify this. But, you know, as I stand here right now</p> <p>21 that's the first -- let's call it the first order analysis.</p> <p>22 Q. (By Mr. Hart) That higher hydrocarbon fuels will</p> <p>23 experience shorter auto-ignition times than lower hydrocarbon</p> <p>24 fuels like methane?</p> <p>25 MR. BEST: Objection; form.</p>
<p style="text-align: right;">Page 22</p> <p>1 Q. Sure.</p> <p>2 A. Are you referring to specifically the passage after</p> <p>3 Column 9, 34 to 37? Is that what you are referring?</p> <p>4 Q. I am. That's exactly right. That's when you start</p> <p>5 discussing an example of pentane and methane.</p> <p>6 How about this: Do you want to start reading there to</p> <p>7 the end of Paragraph 45 and let me know when you're ready and</p> <p>8 I'll ask you some questions?</p> <p>9 A. Sure. Sure. The specification gives the example of</p> <p>10 using pentane, C5 H12, which has approximately --</p> <p>11 Q. Doctor, let me -- I'm sorry. Just to relieve Paula's</p> <p>12 obligation having to get all that down can you read that to</p> <p>13 yourself and let me know when you are ready for some questions.</p> <p>14 A. I'm sorry, I apologize.</p> <p>15 Q. No problem. Thanks.</p> <p>16 A. Okay. I'm done reading it.</p> <p>17 Q. Very good. One thing you note in this paragraph is</p> <p>18 that pentane has a much higher energy content than methane.</p> <p>19 Is that correct?</p> <p>20 A. Well, it depends -- and it's qualified in this passage</p> <p>21 as you see here. By volume it is correct, by mass it's not.</p> <p>22 Q. I would like to explore how auto-ignition timing</p> <p>23 relates to the specific fuel or fuel mixture introduced into a</p> <p>24 system.</p> <p>25 Let's consider two examples. We'll use the pentane</p>	<p style="text-align: right;">Page 24</p> <p>1 A. In general that is correct.</p> <p>2 Q. (By Mr. Hart) Okay. Let's scroll down to Paragraph</p> <p>3 47 in your declaration.</p> <p>4 A. Okay. I am there.</p> <p>5 Q. Very good. So in your second sentence in this</p> <p>6 paragraph that begins because the UFLs of many fuels: Do you</p> <p>7 see that?</p> <p>8 A. I do.</p> <p>9 Q. Okay. In parenthesis in that sentence you note that</p> <p>10 in particular ethane and methane have similar UFLs.</p> <p>11 Do you see that?</p> <p>12 A. I do.</p> <p>13 Q. You continue on: In most circumstances where there</p> <p>14 would be auto-ignition upstream of the combustion zone, for</p> <p>15 example, ethane in scenario one, the properties of the combined</p> <p>16 fuel mixture in scenario two adding methane would generally also</p> <p>17 be susceptible to auto-ignition assuming all else is kept equal.</p> <p>18 Do you see that?</p> <p>19 A. Yes. I see that passage, uh-huh.</p> <p>20 Q. Assuming all else is kept equal would you agree that a</p> <p>21 mixture of ninety percent ethane and ten percent methane would</p> <p>22 have a shorter auto-ignition time than a mixture with ten</p> <p>23 percent ethane and ninety percent methane?</p> <p>24 MR. BEST: Objection to form; beyond the scope;</p> <p>25 incomplete hypothetical.</p>

<p style="text-align: right;">Page 25</p> <p>1 A. I mean that's something that requires more analysis.</p> <p>2 And, again, per this example here ethane and methane are very</p> <p>3 close in terms of their properties. They differ by one C</p> <p>4 number.</p> <p>5 So while the trend that we were talking about a moment</p> <p>6 ago, you know, applies in general and is particularly accurate</p> <p>7 when you are talking about hydrocarbons that are far apart on</p> <p>8 the C chain rank -- when you are talking about methane to ethane</p> <p>9 specifically and now you're reaching the point where, you know,</p> <p>10 you only have one and two Cs, it's the very bottom of the</p> <p>11 hydrocarbon chains, the differences are a lot more subtle and a</p> <p>12 lot more -- a lot smaller.</p> <p>13 So ninety percent ethane, ten percent methane</p> <p>14 versus -- what did you say? Ten percent ethane ninety percent</p> <p>15 methane, is that what you said?</p> <p>16 Q. (By Mr. Hart) That's correct.</p> <p>17 A. You know, following the general trend of reaction</p> <p>18 would suggest that the former would have a shorter ignition</p> <p>19 time.</p> <p>20 But, really I would want to see some numbers. I would</p> <p>21 want to see some analysis carried out here to verify that that</p> <p>22 is indeed the case for these particular concentrations you</p> <p>23 suggested.</p> <p>24 Q. All right. Changing topics a bit.</p> <p>25 Can we scroll up one paragraph to Paragraph 46?</p>	<p style="text-align: right;">Page 27</p> <p>1 Q. Okay. If you mix a pure hydrocarbon strain such as</p> <p>2 natural gas with no or minimal oxygen with a vaporized fuel such</p> <p>3 as ethane the resulting mixture would be above the upper</p> <p>4 flammability limit of the mixture and would not combust.</p> <p>5 Correct?</p> <p>6 MR. BEST: Objection; form; including incomplete</p> <p>7 hypothetical; beyond the scope.</p> <p>8 A. I'm sorry, could you repeat your example, please?</p> <p>9 Q. (By Mr. Hart) Yes. So the mixture is a pure</p> <p>10 hydrocarbon stream such as natural gas with no or minimal oxygen</p> <p>11 combined with a vaporized fuel such as ethane.</p> <p>12 And I'm asking whether the resulting mixture would be</p> <p>13 above the upper flammability limit such that combustion could</p> <p>14 not occur.</p> <p>15 MR. BEST: Same objections.</p> <p>16 A. Right. You're describing a blend of two fuels</p> <p>17 together with no oxygen -- no oxidizer whatsoever. So, yeah.</p> <p>18 This substance that you've described -- and fuel would</p> <p>19 necessarily be above UFL because, you know, the ratio is</p> <p>20 essentially infinite. There is no air in the mixture. There is</p> <p>21 no oxidizer in the mixture. No possibility of auto-ignition.</p> <p>22 Q. And generalizing this concept a bit if you mix any</p> <p>23 vaporized fuel with any reduced oxygen stream containing</p> <p>24 hydrocarbons so long as the resulting mixture remains above the</p> <p>25 upper flammability limit that mixture will not experience</p>
<p style="text-align: right;">Page 26</p> <p>1 A. Okay. I am there.</p> <p>2 Q. All right. So the second page that Paragraph 46 spans</p> <p>3 you have a sentence that starts: A vaporized fuel in the</p> <p>4 absence of air.</p> <p>5 Do you see that?</p> <p>6 A. I do.</p> <p>7 Q. Okay. Let me read that in and then I'll ask you a</p> <p>8 question. You note a vaporized fuel in the absence of air</p> <p>9 (i.e., as the source of oxygen) meaning the concentration of O₂</p> <p>10 is zero or nearly zero, would not combust. Adding other</p> <p>11 vaporized/gaseous fuels will not change this as long as the</p> <p>12 mixture stays below above UFL.</p> <p>13 Do you see that -- those two sentences in your</p> <p>14 declaration, Dr. Lemieux?</p> <p>15 A. I do see that, yes.</p> <p>16 Q. And I believe you intended just one of either below or</p> <p>17 above. Which one should we stick with here?</p> <p>18 A. Yeah. Yeah. You're correct. This is a typo in the</p> <p>19 declaration, yeah.</p> <p>20 So we are not burning so, therefore, we are above UFL.</p> <p>21 Q. And that means there is too much fuel in the mixture</p> <p>22 to support combustion. Correct?</p> <p>23 A. Yes. That's correct.</p> <p>24 Q. Relative to air?</p> <p>25 A. Correct. Correct.</p>	<p style="text-align: right;">Page 28</p> <p>1 auto-ignition. Correct?</p> <p>2 MR. BEST: Objection to form; lack of foundation;</p> <p>3 incomplete hypothetical; beyond the scope.</p> <p>4 A. Right. Again, this is not a scenario that I've</p> <p>5 specifically considered in my declaration.</p> <p>6 But, if I understand you correctly you are describing</p> <p>7 a new fuel blend, say ethane and methane together which I think</p> <p>8 is the example you used, which would look a lot like natural</p> <p>9 gas, and you are not adding enough air to take it below UFL.</p> <p>10 And if I understand you correctly in that scenario</p> <p>11 generally speaking then that mixture would not be ignitable.</p> <p>12 Q. (By Mr. Hart) Any mixture of fuel with any gas so</p> <p>13 long as it remains under the upper flammability -- or above the</p> <p>14 upper flammability limit will not combust?</p> <p>15 MR. BEST: Objection to form; same objections,</p> <p>16 plus vague.</p> <p>17 A. Yeah. I mean you have to look at it on a case by case</p> <p>18 basis for sure.</p> <p>19 But, the general concept of flammability limit is as</p> <p>20 you're suggesting, which is any blend of fuel with air in the</p> <p>21 proportions it says there is too much fuel per unit volume of</p> <p>22 air flowing so that we are above its upper -- upper flammability</p> <p>23 limit will not combust.</p> <p>24 MR. HART: Dr. Lemieux, that's all I have for you</p> <p>25 today. Thanks very much for your time.</p>

<p>Page 29</p> <p>1 Tim, I'll turn the witness over to you.</p> <p>2 MR. BEST: Sure. Let's take -- call it ten just</p> <p>3 to gather our notes.</p> <p>4 (Discussion was had off the record.)</p> <p>5 MR. BEST: I have no further questions, so I</p> <p>6 think we are all done.</p> <p>7 MR. HART: Thank you again, Dr. Lemieux, for your</p> <p>8 time.</p> <p>9 (Witness was excused and signature not waived.)</p> <p>10 (Deposition concluded at 3:50 p.m.)</p> <p>11</p> <p>12</p> <p>13</p> <p>14</p> <p>15</p> <p>16</p> <p>17</p> <p>18</p> <p>19</p> <p>20</p> <p>21</p> <p>22</p> <p>23</p> <p>24</p> <p>25</p>	<p>Page 31</p> <p>1</p> <p>2 May 31st, 2023</p> <p>3</p> <p>4</p> <p>5 TIMOTHY BEST, ESQ.</p> <p>Gibson, Dunn & Crutcher, LLP</p> <p>6 333 S. Grand Avenue</p> <p>Los Angeles, CA 90071</p> <p>7</p> <p>8 DEPOSITION OF: PATRICK LEMIEUX</p> <p>9 Dear Mr. Best:</p> <p>10 Please find enclosed your copy of the deposition of PATRICK</p> <p>LEMIEUX taken on May 30th, 2023 in the above referenced case.</p> <p>11 Also enclosed is the original signature page and errata sheet.</p> <p>12 Please have the witness read your copy of the transcript,</p> <p>indicate any changes and/or corrections desired on the errata</p> <p>13 sheet, and sign the signature page before a notary public.</p> <p>14 Please return the executed signature page and errata sheet</p> <p>within 30 days after receiving the transcript.</p> <p>15</p> <p>Thank you for your attention to this matter.</p> <p>16</p> <p>17</p> <p>Sincerely,</p> <p>18</p> <p>19</p> <p>20</p> <p>Paula D. Hefner</p> <p>21</p> <p>22</p> <p>23</p> <p>24</p> <p>25</p>
<p>Page 30</p> <p>1 CERTIFIED REPORTER'S CERTIFICATE</p> <p>RSMo 492.010</p> <p>2</p> <p>3</p> <p>4 I, Paula D. Hefner, a Registered Merit Reporter and</p> <p>Certified Court Reporter, within and for the State of Missouri,</p> <p>5 do hereby certify that there came before me on May 30th, 2023</p> <p>via ZOOM,</p> <p>6</p> <p>PATRICK LEMIEUX,</p> <p>7</p> <p>who was by me first duly sworn to testify to the truth of all</p> <p>8 knowledge touching and concerning the matters in controversy in</p> <p>this cause; that the witness was thereupon carefully examined</p> <p>9 under oath, and said examination was reduced to writing by me,</p> <p>according to my best knowledge and belief; and that this</p> <p>10 deposition is a true and correct record of the testimony given</p> <p>by the witness, and said deposition is herewith returned to PAUL</p> <p>11 HART, ESQ., ERISE IP PA, 5299 DTC Boulevard, Suite 1340,</p> <p>Greenwood Village, Colorado 80111 for filing with the court.</p> <p>12 I further certify that I am neither attorney nor</p> <p>counsel for, nor related nor employed by any of the parties</p> <p>13 hereto, or financially interested in this action.</p> <p>14</p> <p>15</p> <p>16</p> <p>17 _____</p> <p>Paula D. Hefner, Reporter</p> <p>18</p> <p>19</p> <p>20</p> <p>21</p> <p>22</p> <p>23</p> <p>24</p> <p>25</p>	<p>Page 32</p> <p>1 ERRATA SHEET</p> <p>2 Witness: PATRICK LEMIEUX</p> <p>3 DEPOSITION OF: PATRICK LEMIEUX</p> <p>4 Date Taken: May 30th, 2023</p> <p>5 Page # _____ Line # _____</p> <p>6 Should read: _____</p> <p>7 Reason for change: _____</p> <p>8 Page # _____ Line # _____</p> <p>9 Should read: _____</p> <p>10 Reason for change: _____</p> <p>11 Page # _____ Line # _____</p> <p>12 Should read: _____</p> <p>13 Reason for change: _____</p> <p>14 Page # _____ Line # _____</p> <p>15 Should read: _____</p> <p>16 Reason for change: _____</p> <p>17 Page # _____ Line # _____</p> <p>18 Should read: _____</p> <p>19 Reason for change: _____</p> <p>20 Page # _____ Line # _____</p> <p>21 Should read: _____</p> <p>22 Reason for change: _____</p> <p>23</p> <p>24 Witness Signature: _____</p> <p>25</p>

1 STATE OF)
)
2 COUNTY OF)
3 I, PATRICK LEMIEUX, do hereby certify:
4 That I have read the foregoing deposition; that I have
5 made such changes in form and/or substance to the deposition as
6 might be necessary to render the same true and correct; that
7 having made such changes thereon, I hereby subscribe my name to
8 the deposition. I declare, under penalty of perjury, that the
9 foregoing is true and correct.
10 Executed this ____ day of _____, 2023,
11 at _____.
12
13
14 _____
PATRICK LEMIEUX
15
16
17
18 Before me this ____ day of _____, 2023
19 personally appeared the above named individual.
20
21
22 _____
Notary Public
23
24 My Commission expires: _____
25

1	6	analysis 23:19,21 25:1,21	begins 24:6
1 12:4	67 12:4	answers 6:16	big 6:8
12 18:2	9	apologize 22:14	bit 25:24 27:22
2	9 22:3	appears 13:25	blend 27:16 28:7, 20
2008 5:25	A	applies 25:6	bottom 25:10
2009 5:25	absence 26:4,8	apply 23:18	bound 19:5
29 7:24 8:1	Absolutely 16:15	approximately 22:10	bring 17:11
3	accurate 25:6	area 11:14	burning 26:20
30 8:16	actual 17:1	aspects 15:15	C
31 12:1	add 15:24	assume 7:14 14:4	C1 23:17
32 18:1	added 8:8,13	assuming 24:17, 20	C5 22:10 23:17
34 22:3	adding 24:16 26:10 28:9	assumptions 6:4	call 14:25 16:23 23:21 29:2
37 22:3	address 6:22 17:19,25	attempts 13:24	calling 12:18
396 7:21 12:4,9, 13,15,21,24 13:1, 2,5,16,24 14:7,17 15:22,25 17:18,23	affect 20:12 21:7	attorney 6:12	carried 25:21
3:00 5:11	afternoon 5:23	auto 16:19	case 10:19 15:17 25:22 28:17
3:50 29:10	agree 13:20 14:1 17:18 24:20	auto-ignition 12:8, 10 13:5,16,23 16:1,11,18 17:2,3, 5,20 19:15,22 20:13,19,22,24 21:3,7,8,10 22:22 23:9,10,16,23 24:14,17,22 27:21 28:1	Certified 5:4,5
4	AGREED 5:1	aware 10:22 12:13	chain 25:8
43 19:8,10	ahead 13:21 15:3 18:15	B	chains 25:11
45 21:17,20 22:7 23:2	aims 12:21	back 17:11	chamber 23:10
46 25:25 26:2	air 8:9,12,18,23 9:10 10:14 11:16 12:16 13:6 14:7 18:11,20,21,24 19:1,13,14,20 20:2 23:3,6 26:4, 8,24 27:20 28:9, 20,22	based 19:19	change 26:11
47 24:3	alluding 21:13	basic 6:3 11:12	Changing 25:24
5	amount 13:6 18:11,20,24	basics 7:20	characteristics 8:11
56 12:4		basis 18:25 28:18	chemical 15:4,8
		beginning 16:13	chemistry 14:23, 24
			circumstances 24:13
			claims 13:2 15:21 17:23
			clear 6:5,20 13:12

close 25:3	conference 6:23	define 15:10	discussion 19:19 21:23 29:4
Column 12:4 22:3	connects 14:5	defines 18:10	Doctor 22:11
combined 24:15 27:11	considered 15:15 16:6,10 28:5	definition 8:14 15:14 19:25	documents 7:10
combust 9:5,10 12:16 13:7 14:8 19:14 20:2 26:10 27:4 28:14,23	content 21:2 22:18	depend 10:20	<hr/>
combustion 7:20 8:2,3,4,7,8,10,12, 13,17,24 9:7,8,9, 10,11,19,23 10:13,16,23,24 11:7,9,14,18,23 12:11,17 14:6,9 15:12,16 16:1,3,4, 13,19 17:5,6,21 18:12,24 19:2,15, 22 20:3 21:22 23:4,6,9 24:14 26:22 27:13	context 13:4 15:20,21,24 17:14,23	dependent 21:12	E
combustor 8:19, 22 9:3 10:5,20 11:13,14,21 14:20 16:14	continue 8:16 24:13	depends 9:1 22:20	easier 7:11 13:15
combusts 16:4 19:11	control 7:12	deposed 5:24,25	electronic 7:7
common 11:8	conversation 11:15	deposition 5:3,11 29:10	end 22:7
compared 16:13	converse 18:23	describe 13:15,19 16:17	energy 21:2 22:18
completed 6:16	copies 7:11	describes 12:10	engineering 10:20
compound 16:8 23:13	copy 7:3,5,7,15	describing 10:3,4, 9 11:4,20 12:8 13:19 15:25 27:16 28:6	enter 6:13
concentration 19:12 26:9	correct 9:12 10:17 12:17 13:4 18:10 19:5,22 22:19,21 24:1 25:16 26:18, 22,23,25 27:5 28:1	description 11:6,8 14:14	enters 8:18 11:14
concentrations 25:22	correctly 28:6,10	design 16:14	equal 24:17,20
concept 18:5 27:22 28:19	counsel 5:2	designed 9:9 23:8	Erise 6:21,22,24
concluded 29:10	Court 5:4,13,19 6:8 13:3	desires 9:5	essentially 27:20
conclusion 12:19	Cs 25:10	device 9:7,9 17:21 23:4,6,8	establishing 14:19
	<hr/>	differ 25:3	ethane 24:10,15, 21,23 25:2,8,13, 14 27:3,11 28:7
	D	difference 16:25	events 9:21
	<hr/>	differences 25:11	EXAMINATION 5:21
	declaration 7:3, 15,23 12:1 13:17 14:14 15:6,16 16:7 17:11,19 18:2 19:8 21:17 24:3 26:14,19 28:5	diffusion 8:3,7,12, 15	examples 22:25 23:8
	Defendant 5:2	directly 8:13 21:12	excused 29:9
		discuss 18:5 19:11 21:14,20	exhibit 7:9
		discussed 13:5,17 15:11 23:1	expect 23:18
		discusses 17:18	experience 23:9, 10,16,23 27:25
		discussing 22:5	explore 22:22
			expressly 5:7
			extensive 12:20
			extensively 13:1

F	16:9 17:9,22 23:14 28:2	God 5:17	I
fact 19:5	frame 6:1	good 5:23 6:2 7:19 8:1 9:6 11:25 12:3 17:17 18:1,5 21:19 22:17 24:5	i.e 19:14 26:9
factor 20:14	front 9:12	ground 6:3	identifies 13:17
factors 20:1,6,12, 15 21:7	fuel 8:8,9,12,18,23 9:18 10:15 11:16 12:16 13:6 14:7 16:3 18:11,20,21, 24,25 19:1,2,11, 12,20 20:2,8 21:1, 2,13 22:23 24:16 26:3,8,21 27:2,11, 18,23 28:7,12,20, 21	guess 9:20	ignitable 28:11
fails 9:10	fuels 16:2 21:9	H	ignition 12:20 16:13,19,25 17:1 25:18
fair 10:14 11:10	23:22,24 24:6	H12 22:10	implies 8:17
falls 23:4,7	26:11 27:16	halfway 21:20	included 18:11
familiar 14:23 15:4	fundamentally 8:14	hand 5:14	including 9:13 10:1,25 12:18 13:8 15:1,2,18,19 19:23 21:4 27:6
fashion 16:7	G	happen 20:10	incomplete 19:24
faster 23:11	gas 9:7,8,10 10:15,22 11:16 27:2,10 28:9,12	happy 14:17	20:4 24:25 27:6 28:3
feel 14:16	gather 29:3	Hart 5:22 6:25 7:1 9:6,20 10:10,22 11:6,15,25 12:23 13:13,21 14:22 15:8,15,24 16:16 17:4,13,17 18:1, 17 19:7 20:1,15, 21 21:1,16 23:22 24:2 25:16 27:9 28:12,24 29:7	inconsistent 10:5
find 7:11	gathered 9:16	heating 21:12	incorrect 18:16
fine 7:1 16:23	general 9:5 10:11 17:24 20:25 23:15 24:1 25:6,17 28:19	HEFNER 5:3	infinite 27:20
finish 6:17 13:22	generalizing 27:22	helpful 7:17	influence 20:1,21, 24 21:2
firm 6:24	generally 8:2,11	high 20:18	instance 20:17
fit 7:13	21:8 23:15 24:16	higher 22:18	intended 12:11
flame 8:3,7,12	28:11	23:15,22	16:4,19 17:6
9:12	geometry 9:1	Hold 21:24	26:16
flammability 18:6,	get all 22:12	hydrocarbon	interpreted 13:3
7,10,18,19,22	give 5:15 6:13	23:16,22,23 25:11	16:12
19:20,21 20:9	12:6 15:13	27:1,10	interrupt 6:15
23:5,7 27:4,13,25		hydrocarbons	introduced 10:15
28:13,14,19,22		23:1 25:7 27:24	11:17 14:7 16:2
flow 20:17,18		hypothetical	22:23
flowing 28:22		19:24 20:5 24:25	involve 10:23
focusing 14:20		27:7 28:3	involves 11:13
form 8:25 9:13			IP 6:21,24
10:1,25 11:8,19			issue 12:10
12:18 13:8 14:10			
15:1,18 16:7,8,21			
17:8,22 19:4,23			
20:4 23:13,25			
24:24 27:6 28:2,			
15			
foundation 10:2			
13:9 14:11 15:19			

<p>J</p> <p>job 6:5</p> <hr/> <p>K</p> <p>kind 6:8 9:20 10:4, 11,23</p> <p>kinetics 14:23,24 15:4,8</p> <hr/> <p>L</p> <p>lack 10:1 13:8 14:10 15:18 16:9 17:9,22 23:13 28:2</p> <p>large 9:2</p> <p>law 6:24</p> <p>layout 9:21</p> <p>lead 19:15</p> <p>lean 8:3</p> <p>legal 12:19</p> <p>Lemieux 5:23 26:14 28:24 29:7</p> <p>LFL 20:9,19</p> <p>limit 18:7,10,19,22 20:9 27:4,13,25 28:14,19,23</p> <p>limits 19:6,21 20:8,9</p> <p>Lines 12:4</p> <p>local 7:15</p> <p>logistical 6:15</p> <p>long 26:11 27:24 28:13</p> <p>lot 25:11,12 28:8</p> <p>lower 18:6,10,19 19:21 20:8 21:12</p>	<p>23:23</p> <hr/> <p>M</p> <p>make 13:12</p> <p>mass 22:21</p> <p>maximum 18:23</p> <p>meaning 26:9</p> <p>means 10:6 26:21</p> <p>Merit 5:5</p> <p>methane 21:21 22:5,18 23:1,6,11, 17,24 24:10,16, 21,23 25:2,8,13, 15 28:7</p> <p>middle 12:3</p> <p>mind 6:13</p> <p>minimal 27:2,10</p> <p>minimum 18:11, 20 20:6 21:10</p> <p>mismatch 16:12</p> <p>mix 18:11 19:1 23:3,5 27:1,22</p> <p>mixed 18:24</p> <p>mixing 8:9 21:21</p> <p>mixture 8:18 9:4, 9,11 11:17 12:16 13:6 16:3 18:21 19:13,20 20:2 22:23 23:4,7,10, 11 24:16,21,22 26:12,21 27:3,4,9, 12,20,21,24,25 28:11,12</p> <p>model 11:3</p> <p>moment 12:6 25:5</p> <p>multiple 13:9 14:11 16:9 23:13, 14</p>	<p>N</p> <p>natural 9:7,8,9 10:22 27:2,10 28:8</p> <p>necessarily 10:6 27:19</p> <p>ninety 24:21,23 25:13,14</p> <p>Notary 5:6</p> <p>note 8:1,7,9 22:17 24:9 26:8</p> <p>noted 16:17</p> <p>notes 29:3</p> <p>number 25:4</p> <p>numbers 25:20</p> <hr/> <p>O</p> <p>O2 26:9</p> <p>object 6:12</p> <p>objection 8:25 9:13 10:1,25 11:19 12:18 13:8 14:10 15:1,18 16:8,21 17:8,22 18:13 19:4,23 20:4,16 23:13,25 24:24 27:6 28:2, 15</p> <p>objections 6:14 10:18 11:11 13:18 15:9 17:15 20:23 21:4 27:15 28:15</p> <p>obligation 22:12</p> <p>occur 16:20 20:13, 19,22 21:3,11 27:14</p> <p>occurs 10:16 12:11,16 16:13,18</p>	<p>17:5</p> <p>offers 13:25</p> <p>online 7:9</p> <p>operating 6:3</p> <p>opine 21:14</p> <p>opined 7:22 13:1 14:14 15:5 21:6</p> <p>order 23:16,21</p> <p>oxidizer 8:8 9:18 19:13 27:17,21</p> <p>oxygen 10:14 26:9 27:2,10,17,23</p> <hr/> <p>P</p> <p>p.m. 5:11 29:10</p> <p>paragraph 7:23 8:1,16 12:1,3 18:1 19:8,10 21:17,20 22:7,17 23:2 24:2, 6 25:25 26:2</p> <p>Pardon 15:1</p> <p>parenthesis 24:9</p> <p>part 6:6 13:14</p> <p>parts 13:11</p> <p>passage 22:2,20 24:19</p> <p>patent 7:21 12:4,9, 13,15,21,24 13:1, 2,5,11,14,16 14:7, 17 15:25 17:24</p> <p>path 9:22 10:12,23 11:7 14:5</p> <p>Paul 6:25 7:1</p> <p>PAULA 5:3</p> <p>Paula's 22:11</p> <p>pentane 21:21 22:5,10,18,25 23:3,10,17</p>
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percent 24:21,23 25:13,14 phase 8:13 phenomena 12:8 phenomenon 15:12,25 phrase 14:23 phrases 17:7,14 pinning 7:20 place 8:10 Plaintiff 5:2 point 6:8,15 9:4 10:11 11:16 13:13 20:20 21:7,10 25:9 possibility 27:21 potential 19:15 pre-mixed 10:5 pre-mixer 9:2,17, 22 10:7,21 11:23 precise 15:14 prefer 7:1 preferred 16:22 premature 16:1 17:3 23:9 premise 11:12 premised 15:12 premix 8:17,18 9:7 10:22,24 11:6,9, 13,21 14:5,8 23:6 premixed 8:3,22 9:8 10:12 17:21 23:4 premixing 8:13 11:14 prepared 15:6,10 21:14	preparing 15:16 16:7 present 18:21 19:13 presenting 14:15 pressure 20:21,24 preventing 12:21 printed 7:7 probe 12:23 problem 12:15,22, 24 13:5,16,23,25 14:1,6 17:18 22:15 problematic 13:16 proceed 6:19 proceeding 7:4,21 process 16:15 processes 8:2 properties 24:15 25:3 proportion 9:18 proportions 28:21 provide 13:24 Public 5:6 pure 27:1,9	<hr/> R <hr/> raise 5:13 range 23:5,7 rank 25:8 ratio 27:19 reach 8:23 9:4 10:16 14:9 16:3 reaches 9:11 11:17 12:16 reaching 25:9 react 19:14 reaction 25:17 reacts 19:11 read 22:12 26:7 reading 22:6,16 ready 22:7,13 Real-time 5:5 reason 7:16 reasonable 11:8 13:10 record 6:14 15:14 29:4 reduced 27:23 refer 6:25 11:16 16:12 17:4 18:6 references 12:20 referencing 7:15 referred 14:22 19:20 21:8 referring 13:11 15:22 17:1 22:2,3 refers 12:10,13 Registered 5:5 related 19:12	relates 22:23 relationships 16:6 Relative 26:24 relevant 7:21 17:12 relieve 22:11 remains 27:24 28:13 repeat 9:15 27:8 reporter 5:4,5,13, 19 6:8 representation 17:24 required 8:23 requirement 20:7 requires 25:1 research 15:13 21:15 reserved 5:7 respects 13:9 14:11 16:9 23:13, 14 resulting 23:4,7 27:3,12,24 room 6:13,23 rule 23:15 rules 6:3 Ryan 7:9,17
	<hr/> Q <hr/> qualified 22:20 quantifiable 11:22 question 6:6 9:15 26:8 questions 5:22 6:5,19 7:14 22:8, 13 29:5 quote 12:5 quoting 12:4	<hr/> S <hr/> satisfies 11:12 satisfy 11:3 scenario 23:18 24:15,16 28:4,10 scope 9:14 10:2 11:1 14:12 15:2 17:8 21:5 24:24	

27:7 28:3 screen 6:21 7:10, 16 scroll 11:25 19:7 21:16 24:2 25:25 scrolling 7:12 sense 16:10 sentence 19:10 24:5,9 26:3 sentences 26:13 separated 9:3 14:5 sequence 9:21 set-up 10:4,21 11:3,12,22 14:17, 21 set-ups 11:24 share 7:10,16 shorter 16:2 17:20 23:23 24:22 25:18 shorthand 5:3,4 showed 10:8 sic 20:19 signature 5:7 29:9 similar 24:10 simultaneously 8:10 situation 17:19 smaller 25:12 So-called 8:17 solution 13:24 solve 13:25 solving 13:24 sooner 23:16 sort 17:11 source 26:9	spans 26:2 speak 6:10 speaking 8:2 28:11 specific 10:4,19 11:20 21:1 22:23 specifically 12:14 14:16 15:22 17:11 21:21 22:2 25:9 28:5 specification 22:9 spend 14:19 spontaneously 20:2 stand 23:20 start 7:19 22:4,6 starting 5:11 starts 18:2 26:3 state 8:9 19:11 stays 26:12 stick 26:17 STIPULATED 5:1 strain 27:1 stream 27:10,23 submitted 7:4 substance 27:18 subtle 25:11 suggest 25:18 suggested 25:23 suggesting 28:20 support 18:12 19:2,22 26:22 survey 11:2 susceptible 24:17 sustained 18:25	swear 5:15 system 6:23 8:12, 15 9:1,8 11:9 13:25 14:15 16:2 21:22 22:24 systems 7:20 8:3, 4,7,17 10:13,23 <hr/> T <hr/> takes 13:6 talking 15:21 25:5, 7,8 target 12:17 targeted 12:15 16:25 tech 7:9 technical 15:11 temperature 20:17,18,24,25 21:9 ten 24:21,22 25:13,14 29:2 tendency 19:14 term 15:11 terminology 16:22 terms 13:2 16:16 25:3 testimony 5:15 thing 22:17 things 17:9 23:14 thumb 23:15 Tim 29:1 time 5:11,25 6:9, 12 8:23 9:4,11,23 10:12,16 11:16, 17,18,22 13:6 14:19 16:2,3,18, 19,25 17:1,4,5,6,	20 24:22 25:19 28:25 29:8 times 16:17,22 23:23 timing 15:15,20,23 16:6,10 22:22 today 6:5 15:6 28:25 today's 11:15 topics 25:24 transcribed 5:6 transit 8:23 9:4, 11,22,23 10:12, 15,23 11:7,18 14:5 16:3 17:6,20 trend 25:5,17 true 14:6 19:25 truth 5:16 turn 7:23 18:1 29:1 Turning 8:16 type 11:12,20 types 7:20 typewriting 5:6 typically 7:11 9:2 typo 26:18 <hr/> U <hr/> UEL 20:19 UFL 20:9 26:12,20 27:19 28:9 UFLS 24:6,10 uh-huh 8:15,21 12:14 19:18 24:19 understand 6:6 16:24 17:7,10,13, 16 28:6,10
--	---	--	---

understandable

6:18

understanding

12:24

unit 28:21**unmixed** 8:8**upper** 18:7,17,22

19:21 20:9 27:3,

13,25 28:13,14,22

upstream 12:11

19:15,22 20:2

23:11 24:14

V

vague 15:2,19

28:16

vaporized 26:3,8

27:2,11,23

vaporized/**gaseous** 26:11**variety** 20:12**verify** 23:20 25:21**versus** 25:14**volume** 18:21

22:21 28:21

W

waived 29:9**whatsoever** 27:17**withstands** 9:10**witnesses** 7:11**work** 10:7

Z

zone 8:8,13,24

9:3,11,24 10:16,

24 11:7,8,14,18,

23 12:11,17 14:5,

6,8,9 16:4,5

19:16,22 20:3,11

24:14

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Witness Signature: _____

1 STATE OF)

2 COUNTY OF)

3 I, PATRICK LEMIEUX, do hereby certify:

4 That I have read the foregoing deposition; that I have
5 made such changes in form and/or substance to the deposition as
6 might be necessary to render the same true and correct; that
7 having made such changes thereon, I hereby subscribe my name to
8 the deposition. I declare, under penalty of perjury, that the
9 foregoing is true and correct.

10 Executed this 14th day of June, 2023,
11 at 2:32pm.

12
13
14 
PATRICK LEMIEUX

15
16 6/14/23 KA

See Attached for
Notary Certificate

17
18 Before me this _____ day of _____, 2023
19 personally appeared the above named individual.

20
21
22 _____
Notary Public

23
24 My Commission expires: _____
25

California Jurat Certificate

A notary public or other officer completing this certificate verifies only the identity of the individual who signed the document to which this certificate is attached, and not the truthfulness, accuracy, or validity of that document.

State of California

County of SAN LUIS OBISPO

} S.S.

Subscribed and sworn to (or affirmed) before me on this 14 day of June,
Month

20 23, by Patrick Lemieux _____ and
Name of Signer (1)

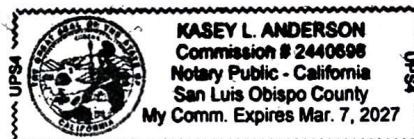
_____, proved to me on the basis of
Name of Signer (2)

satisfactory evidence to be the person(s) who appeared before me.

Kasey L. Anderson
Signature of Notary Public

Notary Public

For other required information (Notary Name, Commission No. etc.)



Seal

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Description of Attached Document

The certificate is attached to a document titled/for the purpose of

Deposition of Patrick Lemieux

containing 40 pages, and dated 5/30/23

Additional Information

Method of Affiant Identification

Proved to me on the basis of satisfactory evidence:
☐ form(s) of identification ☐ credible witness(es)

Notarial event is detailed in notary journal on:

Page # _____ Entry # _____

Notary contact: _____

Other

☐ Affiant(s) Thumbprint(s) ☐ Describe: _____